The Curious Relationship Between COVID-19 Lockdowns and Urban Heat Islands

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Key Points:
- COVID-19 lockdown led to reduced urban heat island (UHI) magnitude in China
- Anthropogenic activity and waste heat is related to UHI magnitude
- UHI mitigation has implication for health, energy, and equity within cities

Abstract The COVID-19 pandemic has been a life-altering shock to society. However, there have been serendipitous outcomes from the associated lockdowns ranging from improved air quality to reductions in carbon emissions. Liu et al. (2022, https://doi.org/10.1029/2021GL096842) revealed that even the magnitude of the heat islands in Chinese cities were reduced due to a decline in human activities and their associated anthropogenic contributions. These surprising findings have significant implications for understanding intersections among climate, health, energy, urban planning, transportation, and infrastructure.

Plain Language Summary Cities are built with heat-absorbing materials, contain less vegetation than surrounding rural landscapes, and host a variety of heat-emitting activities. For this reason, the central business district and suburban areas are often warmer than their surroundings. These so-called urban heat islands are often associated with inequities in health and energy consumption. Newly published research suggests that COVID-19 lockdowns may have temporarily reduced these human-caused heat islands in Chinese cities.

1. Serendipitous Climate Science: Urban Heat and COVID-19 Lockdown

The COVID-19 pandemic has been a significant stressor on the world. At the time of writing, the virus has been attributed to over 5.7 million deaths globally (Worldometers website, 2022). In the early days of the pandemic, nations applied “lockdowns” to reduce the spread of the virus. Studies have shown that these lockdowns impacted ecosystems and societal activity around the world (Atalan, 2020; Verma & Prakash, 2021).

While the clear message from the COVID-19 pandemic is one of strain, vulnerability, and disruption, there were serendipitous impacts of the lockdown beyond containing the virus. Bauwens et al. (2020), using the metric of atmospheric nitrogen dioxide, revealed significant declines in air pollution. Venter et al. (2020) also provided a comprehensive global analysis using in-situ and satellite data. Their study included nitrogen dioxide and particulate matter. Le Quéré et al. (2020) revealed that carbon dioxide emissions were also lower during COVID-19 lockdowns. Though temporary and unsustainable as human activity normalized after 2020, the COVID-19 lockdown unequivocally revealed that human activities affect climate-warming greenhouse gas emissions and pollution. The lockdown provided a glimpse into how changes in anthropogenic activity can reduce emissions and could be used as guidance for future policy decisions.

Such “unexpected” experiments have been instructive in the past for analyzing surface temperatures. Travis et al. (2004) used the three-day grounding of aircraft activity after the 9/11 attacks to investigate the impact of contrails on regional surface temperatures. Liu et al. (2022) used the COVID-19 lockdown to explore surface temperatures from a different perspective. Employing over 3,700 ground air temperature measurements and NASA satellite data, they revealed declines in the magnitude of urban heat islands (UHIs) across many Chinese cities.

What is an UHI? It is the phenomenon that describes cities having warmer temperatures than rural areas. Luke Howard first describe the UHI in 1820. Over the years, numerous studies (Qian et al., 2022; Zhou & Shepherd, 2009) have discussed why heat islands exist: prevalence of heat-absorbing materials in cities, lack of cooling associated with vegetation, and additional waste heat associated human activities such as transportation and heating-cooling systems. Though the UHI is often referenced as a singular entity, there are actually multiple heat islands. Johnson and Shepherd (2018) summarized three types of heat islands: surface or skin (paved surfaces), canopy (the 2-m air Temperature), and boundary layer (roughly lowest 1 km of the atmosphere). Ferguson and Woodbury (2007) have described a subsurface heat island. Zahn et al. (2021) have even proposed the hydrological
UHI. For broader context, Qian et al. (2022) offers a comprehensive assessment of urbanization, extreme weather, and climate.

Liu et al. (2022) found that both the surface and canopy UHI were reduced during the COVID-19 lockdown. This was initially counterintuitive to me because our study (Jin et al., 2010) found that aerosols can reduce urban surface temperature. That finding would suggest that reduced human-caused aerosols in the atmosphere because of the lockdown might lead to an enhanced UHI. Liu et al. (2022) has renewed my thinking about the particular role of aerosols in surface temperature, and that topic should be examined perhaps using the COVID-19 lockdown perspective. It would be particularly interesting to understand the relative changes and distribution of scattering aerosols in the urban – rural environment during the lockdown periods.

What is particularly compelling about findings of Liu et al. (2022) is that two separate datasets (air temperature and satellite-derived surface temperature) reveal a consistent signal. They attribute the reduced UHI to the anthropogenic heat release term. That term was generally reduced because of road closures, less traffic, and restrictions on industrial activities. It would be compelling to see this work replicated for other countries to any potential geographical, climatological, or seasonal factors. Additionally, it would be instructive in future studies to investigate whether a COVID-19 lockdown signal is detectable in subsurface or hydrological variables.

2. Implications

The clear finding from this work is that the human waste heat term is not a negligible contributor to the UHI. There has been scholarly uncertainty about the role of the anthropogenic term relative to the latent heat or thermal surface terms. Scholars like Fan and Sailor (2005) have consistently noted that the waste heat or anthropogenic release term is a significant contributor to the urban energy balance and must not be ignored.

Although they mention anthropogenic heat release, an important limitation of the study is that they do not explicitly test how anthropogenic heat reduced in cities as compared to rural locations. They also use proxy information rather than explicit data representing anthropogenic heat release. Other studies have explored these relationships. For example, Kenaway et al. (2021)’s analysis of 21 middle Eastern cities reported reductions in nocturnal surface UHI during lockdowns. Results were inconclusive during daytime hours. Chakraborty et al. (2021) did find a reduction in the daytime surface UHI in their analysis of 300 urban clusters in India. This collection of studies, including Liu et al. (2022), establishes the possibility that lockdowns (or other sustained periods of reduced human activity) may be reasonable proxies for anthropogenic waste heat. The studies also further amplify the logic that UHI mitigation strategies must consider the waste heat term. Why does this all of this ultimately matter?

Extreme temperatures are typically the deadliest weather and climate hazard, particularly in the United States. Heat accounts for significant health risks, mortality, and morbidity and also creates challenges for energy, ecological, energy and technological systems. As greenhouse gas-driven climate change continues to warm the atmosphere, residents of urban environments will experience a triple threat: a mean warmer climate system, more intense and/or frequent heatwaves, and the UHI.

At the nexus of society and climate extremes, vulnerability is a key concept. It is primarily comprised of three components (Binita et al., 2015): exposure to the weather-climate extreme, sensitivity, and the ability to bounce back (adaptive capacity). A robust body of literature (Hoffman et al., 2020; Shepherd, 2022) has established that racial discrimination, redlining, segregation, and economic disparities increase the vulnerability of certain groups to weather-climate extremes. In an urbanized society, extreme heat and spatially related disparities have disproportionate health and economic impacts on communities of color and the poor.

Though disproportionate racial exposure to urban heat is well-established in the literature (Hsu et al., 2021), our ongoing research in Atlanta, Georgia has established the term “racialized urban heat island (R-UHI)” to describe the phenomenon. In collaboration with scholars at University of Georgia, Georgia Institute of Technology, Arizona State University, and North Carolina A and T State University, we have also explored radical new concepts for engineering cities for thermal justice. Liu et al. (2022) confirm that the waste heat term will need to be central to those efforts going forward.
Data Availability Statement

This paper was an invited commentary. No figures or data were generated for this analysis. Figure 1 was taken from the publicly available NASA Observatory website. Accessed at https://earthobservatory.nasa.gov/images/81870/heat-wave-in-china.

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Figure 1. Land surface temperature in Shanghai, China on 13 August 2013 (Source: NASA Earth Observatory website, https://earthobservatory.nasa.gov/images/81870/heat-wave-in-china).
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