

Global Extreme Temperature Trend Visualization and Regional Climate Inequality Analysis

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Abstract. Climate change as a direct result of human activity has caused a significant shift in the world's climate system. This change has created a marked increase in extreme temperature events, with the most severe impacts being seen in the Global South. This paper examines how extreme global temperature events are evolving over space and time, while also investigating the large socio-economic disparities that are masked by physical climate impacts. Using high-resolution temperature anomaly data that spans from 1940 through 2023 and adjusted to reflect Gross Domestic Product (GDP) per capita by country, this study employs spatiotemporal trend analysis and bivariate scatter modeling to depict not only the accelerating and nonlinear trends of global warming, but also the inequitable distribution of these phenomena geographically. The results indicate what can be referred to as "the vulnerability paradox" whereby developed countries in the global north experience the highest absolute increases in temperature (particularly in high latitudes) yet developing nations in the global south are continuously exposed to life-threatening levels of heat without adequate capacity to adapt to these changes. Extreme temperature trends represent not only a meteorological issue, but also an increasingly pronounced manifestation of structural climate injustice. The results highlight an even greater disconnect between the exposure to climate risk and the resilience of economies, compounding the development gap between the global north and south. Using data science and environmental sociology, this paper contributes to informing equitable global climate governance by promoting differentiated capital allocation from the Loss and Damage Fund.

Keywords: Global extreme temperature, regional climate inequality, GDP

1. Introduction

As a result of human contribution to climate change, people see many different thermodynamic changes across the global climate system that are unprecedented. An increase in average surface temperature over time is one of the macroscopic indicators of climate variation. However, the increase in the frequency, duration and intensity of extreme thermal events is the most significant immediate existential threat to human populations and natural ecosystems. The Sixth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) states that extreme heat waves are now occurring on almost all land masses inhabited by humans and with an alarming rate of occurrence [1]. The global path of climate change has changed from that of linear warming to an

increasingly non-linear acceleration in the frequency of extreme temperature events. This means that the methods used to adapt to the effects of climate change no longer work effectively. There is a need to have detailed mapping of climate dynamics at a regional level. Extreme heat, as a single physical manifestation of climate change, will have many effects on social and economic systems throughout the world. Analysing the differences between the way that regions with high levels of development and regions with low levels of development will experience an extreme event will show that there is significantly greater disruption to the social and economic systems in developed countries compared with developing countries. This discrepancy highlights a fundamental challenge for environmental sociologists: the intersection between spatial climate exposure and economic precarity. A socio-economic analysis that is based on atmospheric data in isolation from each other does not capture the actual human impact of global warming. The fact that disproportionately high numbers of people in marginalised populations bear the burden of the climate crisis shows that it is a multiplying force of threats to people. Climate change does not just warm the planet; it actively creates poverty and food shortages. Ironically, the worst health and environmental impacts hit the exact regions that emitted the least amount of carbon. This harsh reality is exactly why modern climatology has to prioritize climate justice over pure statistics.

People see this injustice acknowledged in political ecology circles quite often, yet hard empirical data is surprisingly rare. Very few researchers actually take the time to map daily temperature spikes directly against local economic resilience. Instead, academic literature usually fractures into two opposite extremes: pure weather forecasting on one side, and abstract sociological theory on the other. The research tries to fix that disconnect. By merging atmospheric data with environmental sociology, scholars can track how historical heatwaves disproportionately damage vulnerable communities in the real world. The core argument here is straightforward. When climate extremes hit specific geographic areas harder, it widens the global wealth gap and actively locks in historical inequalities.

2. Overall trends and visualization of global extreme temperatures

The core data for this section comes from the global monthly surface temperature dataset maintained by Our World in Data (OWID) [2]. To figure out what counts as an "extreme" shift, this paper calculated temperature anomalies using 1951 to 1980 as baseline. The methodology progresses in two simple stages. First, this paper uses line charts to map the historical acceleration of warming over the decades. Then, this study transitions to heat maps to pinpoint exactly where that heat lands geographically. Doing it this way gives people hard numbers to back up later discussions about regional inequality. It's also worth noting a basic statistical reality here. Even a tiny shift in a region's mean baseline temperature inevitably causes a massive, non-linear spike in dangerous heatwaves.

2.1. Temporal trends and visualization of global extreme temperatures

Figure 1 shows the exponential growth in global heat. The blue line tracks the annual anomalies. Notice how, prior to 1980, the numbers basically just bounced around the 0°C mark without much direction. But once 1980 passed, the red trend line completely breaks away. It climbs steeper and faster every single decade. Then there is 2023. That specific year shattered the historical envelope of the past eighty years. It spikes almost vertically on the chart, logging an unprecedented +1.4°C single-year jump.

This isn't just a visual trick on a graph; it matches exactly what major scientific bodies reported for 2023. The World Meteorological Organization (WMO) officially logged 2023 as the hottest year

they have ever seen, smashing all previous records [3]. The IPCC has been warning the world about this exact scenario, noting that extreme heat is escalating at a pace people have never dealt with before [1]. That aggressive red spike in the 2023 data just puts a terrifying visual face on their warnings.

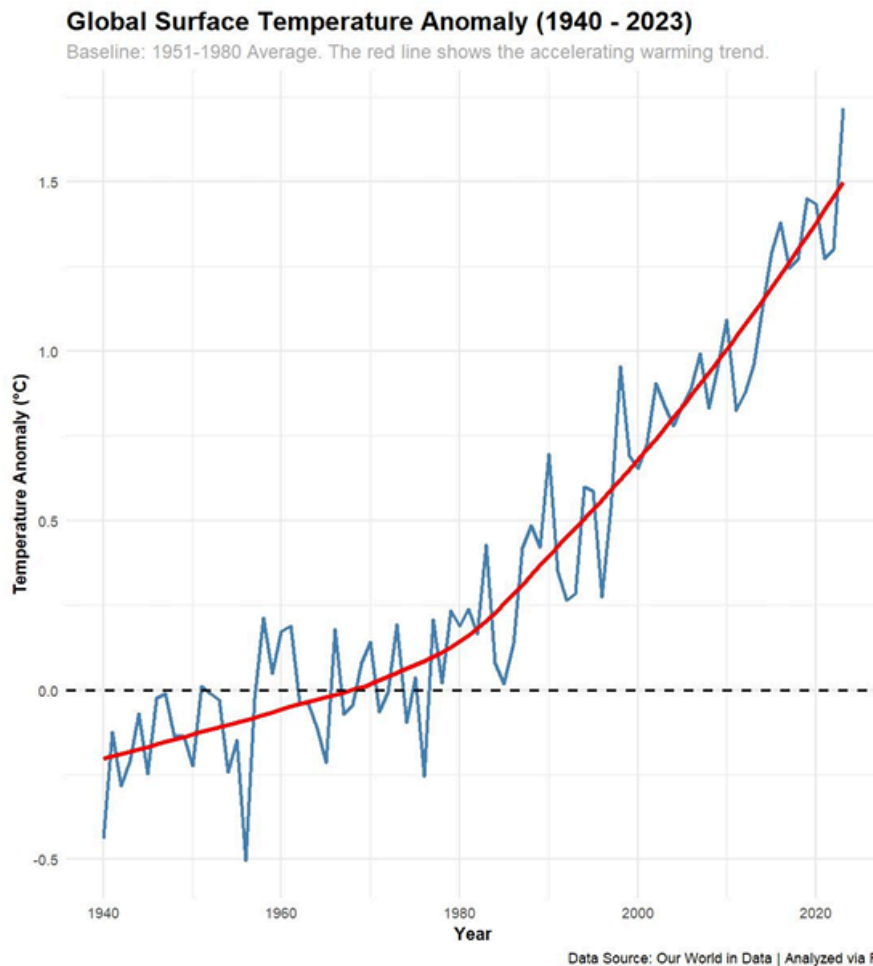


Figure 1. Global surface temperature anomaly trends (1940-2023)

Picture credit : original

2.2. Spatial distribution and visualization of global extreme temperatures

Figure 2 shows the two distinct realities. Up in the Northern Hemisphere's high latitudes, the map bleeds deep red—confirming that these specific areas are warming faster than anywhere else on earth. The results of Africa, South Asia, and South America show an endless stretch of orange and orange-red. That color represents something much deadlier: a continuous, grinding exposure to extreme heat.

This physical gap actually unmasks a massive social equity crisis. The geographic map of extreme heat completely fails to line up with the map of global wealth, creating a textbook case of structural climate injustice. Harrington et al. make a crucial point here: while wealthy, high-latitude nations see the biggest absolute jumps on the thermometer, they have the financial cushion to handle it [4]. Low-latitude nations do not. They are mostly developing economies that critically lack basic

cooling infrastructure, like reliable widespread refrigeration. People there cannot easily adapt when a heatwave refuses to break, which inevitably leads to countless preventable deaths. The bottom line from Figure 2 is brutal. Rich countries have government funds to adapt to temperature swings, while developing nations are left completely exposed. Forcing impoverished regions to absorb extreme heat without resources is the literal definition of "regional climate inequality." It proves exactly why a one-size-fits-all approach to global climate governance will never work.

Global Surface Temperature Anomaly in 2023 (°C vs 1951-1980)

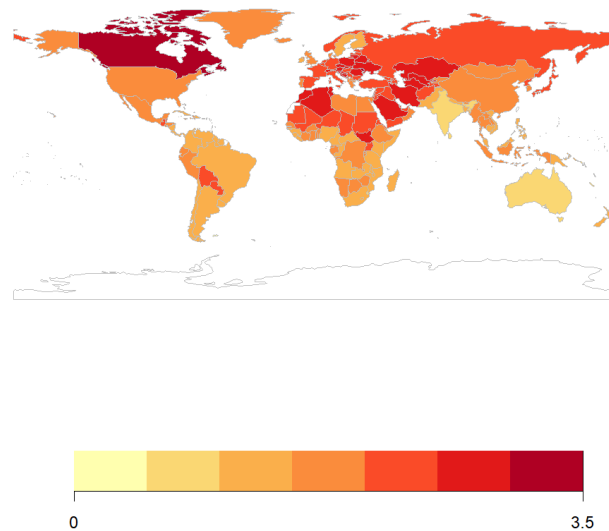


Figure 2. Spatial distribution of global temperature anomalies (2023)

Picture credit : original

3. Regionally differentiated rates of temperature extremes and climate inequality

3.1. Regionally differentiated rates of temperature extremes

Figure 3 tracks continental temperature trends since 1940, and the overall warming acceleration is obvious across the board. But drill down into the data, and the regional differences are striking. Take the mid-to-low latitude regions like Asia and Africa. Their anomaly curves are incredibly smooth, just steadily marching upward. This shows that extreme heat is no longer a freak occurrence in these areas; it has stabilized into a highly predictable, ongoing climatic norm.

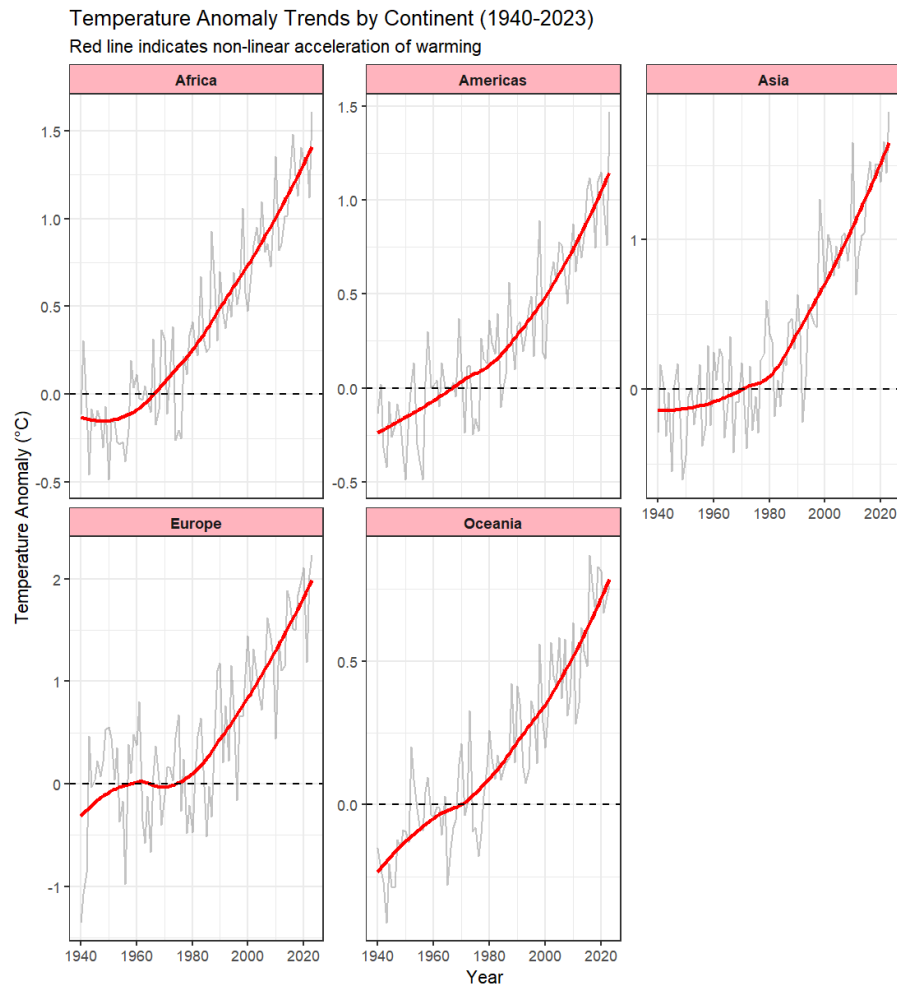


Figure 3. Faceted line chart of regional temperature trends by continent

Picture credit : original

Moving up to higher latitudes like Europe and North America, and the data tells a different story. The long-term trend is still a steep climb, but their data lines look like a jagged saw blade. The climate system up there is growing extremely unstable, driven heavily by the Arctic amplification effect. So, while these higher latitudes are warming rapidly, they are also getting slammed by wild, alternating extremes—including sudden, severe cold snaps. This stark global split lines up perfectly with what scholars have been arguing [5]. The developing world near the equator is getting cooked by a slow, steady rise in baseline heat, while the wealthier North is dealing with chaotic, erratic temperature swings.

3.2. The Climate Vulnerability Paradox - a mismatch of climate change relative risk and absolute warming

Figure 4 deeply counterintuitive "Climate Vulnerability Paradox" emerges. This paper set log-transformed GDP per capita on the X-axis to measure a country's socio-economic armor and plotted the 2023 temperature anomalies on the Y-axis to track the raw physical warming stress. The resulting scatter plot shows a complete structural mismatch. Most developing nations—primarily

from Africa and South Asia—are clustered tightly on the far-left side of the chart, indicating severe limits in per capita wealth.

Meanwhile, developed European nations sit comfortably in the upper right quadrant. Because of polar amplification, these wealthy nations actually absorbed the largest absolute increases in warming (usually seeing anomalies between $+1.5^{\circ}\text{C}$ and $+2.5^{\circ}\text{C}$). By comparison, the severely impoverished nations on the left side of the graph actually recorded lower absolute warming levels, with their anomalies mostly clustering between $+0.5^{\circ}\text{C}$ and $+1.5^{\circ}\text{C}$.

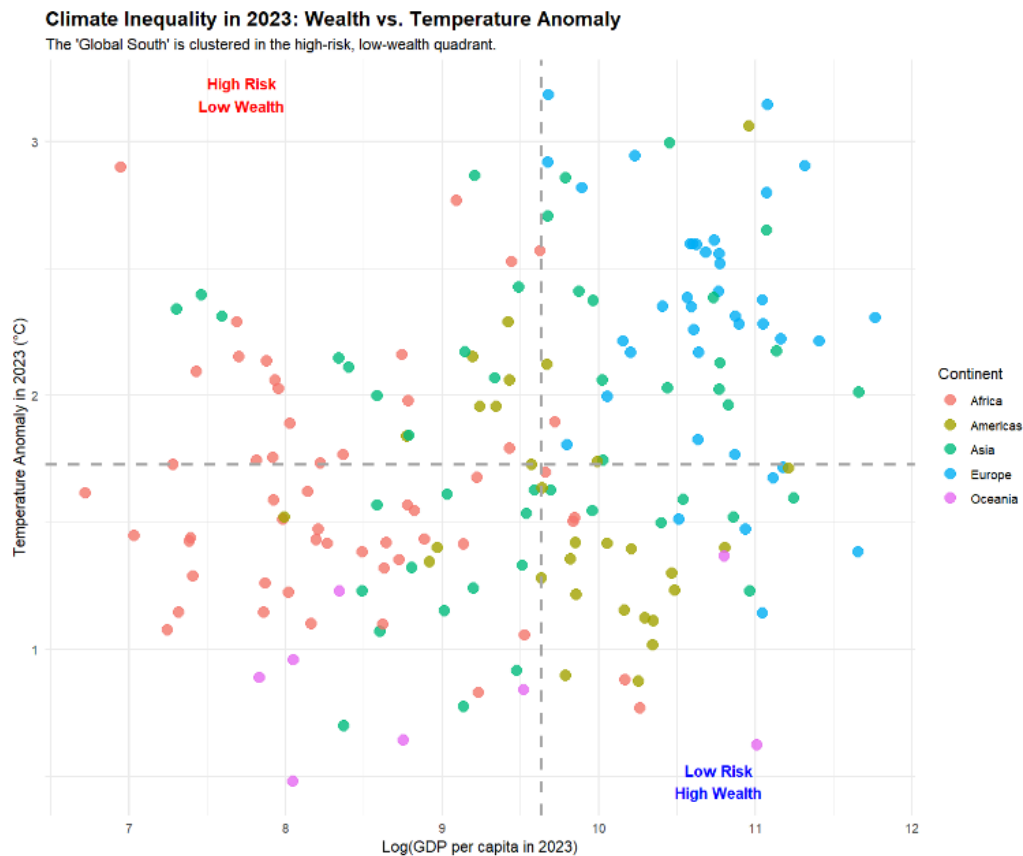


Figure 4. Scatter plot of wealth (log GDP) vs. climate risk (temperature anomaly)

Picture credit : original

Evaluating climate threats solely by absolute warming (the Y-axis) is misleading. This reveals the core of the vulnerability paradox. The world's wealthiest nations sit in the upper right corner of the chart. They face massive surface temperature increases. Yet, their vast capital and robust infrastructure protect them from the worst consequences. On the other side, poorer countries face seemingly smaller temperature jumps. But these nations already exist near the absolute limits of human survival and agricultural collapse. A tiny climate shift triggers utter disaster. Furthermore, they severely lack basic adaptive tools like air conditioning, reliable refrigeration, and early warning networks. As a result, even minor absolute warming becomes deadly. Looking only at physical metrics completely masks the harsh reality: poor, low-latitude countries are dangerously vulnerable to climate disasters [3, 6].

3.3. Primary forms of regional climate inequity

Figures 3 and 4 expose two major socio-economic dimensions of regional climate inequity. The first dimension is the entirely disproportionate burden of lethal climate exposure. Over two centuries of industrialization, high-income countries traded massive carbon emissions for enormous wealth. They successfully made their way into the high-resilience quadrant (on the right side of Figure 4). Meanwhile, they pushed the actual costs of those emissions onto the "Global South." This historical transfer created an extreme geographic and economic divide in global climate risk [7].

The second dimension involves the sheer severity of structural damage. In the high-risk, low-wealth quadrant, a slight temperature rise easily wipes out local agriculture and public health systems. When disasters strike, these nations lack recovery funds. The IPCC warns that this traps them in an endless cycle of poverty. Meanwhile, high-income countries hide behind technological and financial shields. Their climate-related losses usually remain manageable financial setbacks. Clearly, extreme temperatures represent much more than just physical weather anomalies. They actively reshape the modern North-South divide and violently expand the global wealth gap.

4. Policy pathways to mitigate regional climate inequality

4.1. Enhancing global climate governance and climate justice

Governance needs a fundamental shift. High-income nations must fulfill their climate finance promises and actively support the Loss and Damage Fund. Their financial contributions should be strictly tied to their historical cumulative emissions. More importantly, this money must prioritize the highly vulnerable, low-latitude countries first.

Look back at the scatter plot in Figure 4. It exposes a massive spatial mismatch between wealth and climate risk. This proves that the principle of "Common but Differentiated Responsibilities" (CBDR) is not just a political slogan; it is an objective reality backed by hard data. Wealthy nations built their economies heavily on carbon emissions, but they actively offloaded the devastating temperature costs onto impoverished countries. Therefore, global governance cannot focus on reducing future greenhouse gases. It must transition from a system of "voluntary charity" to one of "mandatory restitution." Providing the Global South with substantial, guaranteed financial support is the only way to help them survive these extreme climate impacts.

4.2. Strengthening extreme temperature monitoring and early warning systems

Physical exposure to climate extremes is exacerbated by inadequate meteorological systems in the Global South (e.g., Afghanistan, Bangladesh). These regions are primarily located in the orange-red high-risk zones shown in Figure 2. When a region lacks basic meteorological infrastructure, they operate in a massive "data blind spot." Authorities literally cannot see a lethal heatwave coming until it is too late, leading to horrifying spikes in excess mortality. If people want to stop these preventable deaths, dismantling the technical barriers to early warning systems has to be step one.

Take the WMO's recent "Early Warnings for All" initiative, which promises universal coverage by 2027. It sounds great on paper. But right now, millions of people scattered across Africa and various island nations remain entirely unprotected [8]. Fixing this requires wealthy nations to stop hoarding technology. They have to hand over advanced climate monitoring tools for free and completely open up their satellite data. Then need high-resolution weather grids placed directly inside these danger zones. If local governments finally get a few days' notice, that window changes

everything. It buys them just enough time to stage medical supplies and move people out of the heat zones. It is a straightforward logistical fix that saves lives.

4.3. Fostering regional coordination and joint climate risk management

Pouring money into the Global South is necessary, but money alone won't solve the problem if neighboring countries refuse to talk to each other. Weather doesn't care about borders. A brutal heatwave or cold snap will easily blanket an entire region. When that happens, governments have to instantly tear down their information-sharing walls. If they establish joint emergency protocols beforehand, they can actually route relief supplies across borders the minute things get bad.

The local scale—specifically the Urban Heat Island (UHI) effect. Concrete jungles actively trap heat, turning low-income neighborhoods into literal ovens compared to wealthier suburbs [9]. City planners actually have the tools to fix this. They can carve out ventilation corridors in cramped districts to let the wind blow through, or plant massive amounts of green infrastructure so that natural transpiration cools the streets [10]. At present, some vulnerable groups live under the condition of lacking basic cooling facilities and nearby medical resources, and face significant high-temperature health risks. Public policies should accurately identify high-vulnerability communities, establish a direct mechanism for high-temperature emergency resources, and block the vicious circle of poverty-high-temperature exposure-health deterioration by directly distributing cooling, medical and living security resources to avoid the cumulative transmission of intergenerational poverty and health risks.

5. Conclusion

The global warming trend is becoming more and more obvious, and the unfair distribution of high temperature risk has obvious artificial construction attributes. This study puts forward the fragility paradox, pointing out that the climate crisis stems from the triple structural disconnection: high-income countries rely on fossil fuels to achieve wealth accumulation; Extreme weather risks are geographically targeted; The poorest vulnerable groups lack risk protection resources and self-protection ability, and passively bear the full cost of the climate crisis.

Because of this dynamic, the poorest communities on earth are taking the hardest hits. Just admitting that this system is unfair is nowhere near enough anymore. Actually, fixing it means wealthy countries have to pay up, hand over their climate technology, and start coordinating across borders. Addressing structural climate injustice is no longer an 'optional' policy; it is situationally urgent to ensure a sustainable future for all.

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