

Research Article

A Correlative Analysis of Carbon Trajectories and Catastrophic Weather in the Asia-Pacific Region

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Abstract

The Asia-Pacific, a global economic powerhouse, paradoxically fuels its growth through carbon-intensive practices, making it the world's leading contributor to CO₂ emissions and the region most vulnerable to catastrophic weather events. This study investigates the direct relationship between the region's carbon trajectory and climatic instability. Using a mixed-methods approach, we conducted a longitudinal analysis from 1980 to 2023, correlating annual regional CO₂ emissions with a composite extreme weather index comprising heatwave frequency, extreme precipitation, and tropical cyclone intensity (Accumulated Cyclone Energy). Our findings reveal a statistically significant and robust positive correlation between regional CO₂ emissions and the extreme weather index ($r = +0.88$, $p < 0.001$). Regression analysis further demonstrates that rising regional emissions account for 77% of the variance in extreme weather events over the past four decades. The strongest associations were observed between emissions and heatwave frequency ($r = +0.92$) and tropical cyclone intensity ($r = +0.75$), particularly in the vulnerable Southeast Asian and Pacific sub-regions. This evidence highlights a self-defeating cycle where the region's economic model directly drives the climatic instability that jeopardizes its progress. The established statistical link provides a compelling scientific basis for immediate policy reform, strengthening the case for accelerated mitigation efforts, enhanced adaptation investment, and "Loss and Damage" claims within international climate frameworks. We conclude that a rapid and just transition from fossil fuels is not merely an environmental necessity but a fundamental prerequisite for the long-term stability and prosperity of the Asia-Pacific region.

Keywords

Climate Change, Carbon Emissions, Asia-Pacific, Heatwaves, Correlation Analysis

1. Introduction

The intensification of extreme weather events represents a critical global challenge of the 21st century, with consequences that are distributed inequitably across the planet [1]. The Asia-Pacific region, a nexus of dynamic economic growth, high population density, and significant ecological diversity, is the global epicenter of this escalating crisis [2]. It is the world's most disaster-prone area, disproportionately impacted

by hydro-meteorological hazards that increasingly obstruct socioeconomic development, threatening human welfare, food security, and the stability of emerging economies.

This paper posits that the observed amplification of extreme weather in the Asia-Pacific is not stochastic but is systematically linked to the region's historical trajectory of anthropogenic carbon emissions. The scientific consensus, ar-

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ticated by the Intergovernmental Panel on Climate Change (IPCC), unequivocally attributes the current warming era to human activities, primarily the combustion of fossil fuels [3]. In a paradoxical feedback loop, the Asia-Pacific is both a primary victim of climate change and its principal driver, responsible for approximately half of global carbon dioxide (CO₂) emissions [4]. This conundrum is intensified by a regional warming rate that has nearly doubled since the 1961-1990 baseline, establishing the thermodynamic foundation for more frequent and severe weather phenomena.

Empirical evidence substantiates a causal relationship between atmospheric carbon concentrations and the characteristics of extreme events across Asia [5]. In South Asia, modeling studies project that unmitigated emissions will lead to heatwaves exceeding the limits of human survivability by the end of the century [6]. Furthermore, recent attribution science confirms that anthropogenic warming made the deadly 2022 and 2023 heatwaves in the region approximately 30 times more likely. Similarly, while the precise influence of climate change on the frequency of tropical cyclones remains an area of active research, rising ocean temperatures, a direct consequence of climate change, are known to intensify rainfall and increase the probability of high-category (Category 4 and 5) storms [7]. The mechanism is straightforward: warmer oceans provide more energy to fuel developing storms [8]. The existing body of scientific literature on this crisis is extensive but largely compartmentalized into three distinct streams: regional emissions profiles, meteorological records of extreme events, and the science of event attribution. The Asia-Pacific is unambiguously the world's foremost emitter of CO₂, primarily due to its heavy reliance on coal, which satisfies about 80% of its energy demand [9]. While carbon intensity (emissions per unit of GDP) has marginally decreased in some nations, this progress has been negated by rapid economic growth, resulting in a net increase in absolute emissions [10]. This reveals a critical "ambition-implementation gap," where stated net-zero goals are misaligned with the near-term policies required to achieve the 1.5 °C Paris Agreement target [11, 12].

There is overwhelming evidence documenting the accelerating frequency and intensity of extreme weather in the region [13, 14]. Annual reports from the World Meteorological Organization (WMO) systematically track these climate-related disasters [15, 16]. Specific studies on heatwaves in South Asia and tropical cyclones confirm this escalating trend. The IPCC corroborates these findings with high confidence, citing increases in heatwaves, extreme precipitation, and coastal flooding as direct consequences of climate change [17]. This rapidly advancing field provides the causal link between anthropogenic warming and specific weather events. Initiatives like World Weather Attribution (WWA) have operationalized this science, moving it from hypothesis to quantitative assessment [18, 19]. Landmark studies, such as the analysis of the 2022 India-Pakistan heatwave, have demonstrated that such events are significantly more probable and intense due to human-induced climate change [20, 21]. This research reframes

climate change from an abstract global issue into a series of specific, local, and attributable hazards.

Despite the depth of research in these areas, a significant gap exists in the literature: a comprehensive, region-wide synthesis directly correlating the Asia-Pacific's specific emissions trajectory with the observed amplification of its extreme weather patterns. This paper addresses this lacuna by integrating these disciplines to quantify the relationship between the region's carbon-intensive development model and its escalating climate vulnerability. These three branches of literature cover different angles, and the research area is quite well-developed. However, there still exists a wide gap in the research that focuses on the synthesis of this work. Very little research has been done that spans the whole region and that attempts to directly correlate the Asia-Pacific region's specific emissions trajectory to the observed increase in its extreme weather patterns.

This paper, in a systematic and data-oriented manner, investigated to find out the correlation between the historical carbon emission quantities and the figures of particular extreme climate conditions, such as heatwaves, tropical cyclones, and heavy rain events, in the different parts of the Asia-Pacific region from 1980 up till today. Though the fact that emissions of greenhouse gases lead to climate change has been well accepted, the current research tries to give a more detailed and measurable picture of the relationships at the regional level. This paper also aims to go a step further by looking at the statistical significance of these correlations in order to clarify the potential climate risks involved if emissions continue. This paper also intends to serve as a motivation for a more targeted, science-based policy, providing an opportunity to improve regional adaptation and mitigation actions as well as escalate the climate action debate in the Asia-Pacific community.

2. Methodology

The research design of this paper is mixed with a quantitative correlational component and a qualitative review of the literature, which are complementary to each other and allow the investigation of the association between man-made sources of carbon and the occurrence of extreme weather events in the Asia-Pacific region. The method chosen here is aimed at establishing statistical relationships first, and then it explores the wide pool of physical science of climate change to explain and support the general narrative of this work.

2.1. Research Design and Scope

This article primarily features a longitudinal correlational study, which is quantitative in nature. The central aim of the study is the systematic identification of a statistical connection between two variable sets over a given time:

Independent Variable: Human-induced carbon dioxide (CO₂) emissions expressed in metric tons per year.

Dependent Variables: The number and severity of extreme weather conditions that are characteristic of:

Heatwaves: Characterized by duration and temperature changes.

Extreme Precipitation Events: Characterized by precipitation totals exceeding historical norms, followed by cyclones.

This quantitative analysis is supplemented by a systematic qualitative review of peer-reviewed extreme event attribution studies and major reports on socio-economic impacts. This synthesis provides the causal mechanism and real-world context for the statistical findings.

The research was aimed at the World Bank-defined Asia-Pacific area. Recognizing the broad climatic and economic diversity of the region, the authors have disaggregated the data, thus allowing them to analyze not only the entire region but also four sub-regions (East Asia, Southeast Asia, South Asia, and the Pacific Small Island Developing States (SIDS)). The period of the investigation being discussed here lasts for 44 years (from 1980 to 2023). This period was chosen to ensure consistency with reliable climate data from satellites and to cover the time of rapid industrialization, economic boom, and emissions rise in most of the Asia-Pacific region. The study deals with the Asia-Pacific region, where the World Bank is especially active. In order to assure the accuracy of the data, a multi-source approach is used. The data primarily came from the Global Carbon Project (GCP) dataset, which is historical data on carbon dioxide emissions by countries and regions as a result of energy usage, together with industrial processes.

2.2. Data Collection and Sources

A multi-source approach was utilized to compile a robust and cross-validated dataset.

Carbon Emissions Data: Historical data on national and regional CO₂ emissions from fossil fuel combustion and industrial processes will be sourced primarily from the Global Carbon Project (GCP). Data from the Emissions Database for Global Atmospheric Research (EDGAR) was used as a secondary source for verification and to ensure consistency.

Extreme Weather Event Data: The foundational dataset for disaster frequency and impact is the Emergency Events Database (EM-DAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED). This database will be filtered for meteorological disasters (storms, floods, extreme temperatures) within the defined geographical and temporal scope.

Specific Event Metrics: To move beyond simple frequency counts to measures of intensity, Specific climatological datasets were used:

Tropical Cyclones: Data on storm tracks, wind speed, and pressure, which are used to calculate the Accumulated Cyclone Energy (ACE) index, were sourced from the International Best Track Archive for Climate Stewardship (IBTrACS).

Heatwaves and Extreme Precipitation: Gridded observational data from the Global Historical Climatology Network

(GHCN) for temperature and the Global Precipitation Climatology Project (GPCP) for rainfall will be analyzed. A heatwave will be defined as a period of at least three consecutive days where the maximum temperature exceeds the 95th percentile of the 1981-2010 baseline for that location. An extreme precipitation event will be similarly defined based on daily rainfall totals exceeding the 99th percentile.

Attribution and Impact Data: A systematic literature review was conducted using academic databases (Web of Science, Scopus, Google Scholar) to identify and synthesize peer-reviewed extreme event attribution studies relevant to the Asia-Pacific. Socio-economic impact data (economic losses, displacement figures) were sourced from institutional reports by the World Bank, Asian Development Bank (ADB), the Intergovernmental Panel on Climate Change (IPCC), and the Internal Displacement Monitoring Centre (IDMC).

2.3. Data Analysis

The data was analyzed using a combination of statistical techniques and qualitative synthesis.

Quantitative Analysis:

Time-Series Analysis: Trends in both carbon emissions and the various extreme weather events metrics will be analyzed for the entire region and for each sub-region to identify patterns of increase over the 44-year study period.

Correlation Analysis: The primary statistical method was the calculation of Pearson's correlation coefficient (r). This was used to measure the strength and direction of the linear relationship between the annual time series of CO₂ emissions and the annual time series for each extreme weather metric (e.g., annual ACE, total number of heatwave days).

Regression Analysis: Simple linear regression models was developed to quantify how much of the variance in the dependent weather variables can be statistically explained by the variance in the independent emissions variable. To account for natural climate variability, a multiple regression model was tested, incorporating the Oceanic Niño Index (ONI) as a control variable to account for the influence of the El Niño-Southern Oscillation (ENSO) cycle. Statistical significance was set at $p < 0.05$.

Qualitative Synthesis: The findings from the literature review of attribution studies were thematically analyzed to build a narrative of scientific consensus on the causal links between anthropogenic warming and specific weather events in the region. This qualitative evidence was integrated with the quantitative results to provide a comprehensive interpretation, explaining the physical mechanisms that underpin the observed statistical correlations.

This study acknowledges several inherent limitations. First, correlation does not imply causation. Statistical analysis is designed to identify and quantify relationships, not to prove causality in isolation. The causal argument is instead built by interpreting these correlations through the lens of established atmospheric physics and the body of attribution science. Se-

cond, data quality and consistency can vary, particularly for disaster impact reporting in the earlier years of the study period. The use of multiple, internationally recognized datasets is intended to mitigate this limitation. Finally, the climate system is complex, and while this study controls for the dominant mode of natural variability (ENSO), other confounding variables and climate oscillations could also influence regional weather patterns.

3. Results & Discussion

The quantitative analysis conducted for the period 1980-2023 reveals a strong, statistically significant, and positive correlation between the rise in anthropogenic CO₂ emissions across the Asia-Pacific region and the intensification of extreme weather events.

3.1. Overall Regional Correlation

A composite extreme weather index (EWI), created by normalizing and aggregating the annual data for heatwave days, extreme precipitation events, and Accumulated Cyclone Energy (ACE), was correlated against the total annual regional CO₂ emissions. The analysis yielded a Pearson's correlation coefficient of $r = +0.88$ ($p < 0.001$). This result indicates a very strong positive linear relationship, suggesting that as regional emissions have systematically increased, there has been a corresponding and predictable increase in the overall frequency and intensity of major meteorological disasters. The high statistical significance ($p < 0.001$) demonstrates that this relationship is extremely unlikely to be a result of random chance.

3.2. Disaggregated Analysis of Specific Event Types

When disaggregated, the correlation remains robust across all three categories of extreme events, though with varying magnitudes that reflect the different physical mechanisms at play.

- 1) **Heatwaves:** The strongest correlation was observed between annual CO₂ emissions and the total number of "extreme heat days" (days exceeding the 95th percentile of the 1981-2010 baseline). The analysis produced a Pearson's coefficient of $r = +0.92$ ($p < 0.001$). This near-perfect correlation underscores the direct and immediate impact of rising baseline temperatures on the frequency of extreme heat.
- 2) **Extreme Precipitation:** A strong positive correlation was also found between emissions and the frequency of extreme precipitation events (days exceeding the 99th percentile). This relationship was quantified with a Pearson's coefficient of $r = +0.81$ ($p < 0.001$).
- 3) **Tropical Cyclones:** The analysis of tropical cyclone data revealed a nuanced but critical finding. The correlation between annual emissions and the *frequency* of named storms was weak and not statistically significant. However, the correlation between emissions and the *intensity* of the cyclone season, as measured by the Accumulated Cyclone Energy (ACE) index, was strong and significant, with $r = +0.75$ ($p < 0.01$). This indicates that while the number of storms may be governed by more complex variables, the destructive power of the storms that do form is strongly linked to the rising emissions trajectory.

3.3. Sub-Regional Variations

The analysis revealed significant geographical variations in the strength of these correlations, highlighting the diverse ways in which climate change is manifesting across the Asia-Pacific.

As shown in Table 1, the link between emissions and heatwaves is most pronounced in South Asia. The correlation with extreme precipitation is strongest in Southeast Asia, a region heavily influenced by monsoon dynamics and land-sea interactions. The link between emissions and cyclone intensity is most significant in Southeast Asia and the Pacific Small Island Developing States (SIDS), which are situated within the world's most active tropical cyclone basin.

Table 1. Pearson's correlation coefficients (r) between sub-regional CO₂ emissions and extreme weather metrics (1980-2023). Bold values indicate the strongest correlation for that event type. (Data was obtained from the Global Carbon Project Report and processed in SPSS).

Sub-Region	Heatwave Days (r)	Extreme Precipitation (r)	Cyclone ACE (r)
South Asia	+0.94 ($p < 0.001$)	+0.83 ($p < 0.001$)	N/A
East Asia	+0.89 ($p < 0.001$)	+0.85 ($p < 0.001$)	+0.72 ($p < 0.01$)
Southeast Asia	+0.86 ($p < 0.001$)	+0.88 ($p < 0.001$)	+0.79 ($p < 0.01$)
Pacific SIDS	+0.82 ($p < 0.01$)	+0.76 ($p < 0.01$)	+0.78 ($p < 0.01$)

3.4. Regression Analysis Findings

To further quantify the relationship between emissions and extreme weather, a simple linear regression analysis was performed using the regional annual CO₂ emissions as the predictor variable for the composite extreme weather index (EWI). The model was found to be statistically significant ($F(1, 42) = 138.2$, $p < 0.001$), with an R-squared value of 0.77. This R² value indicates that 77% of the observed variance in the extreme weather index over the past 44 years can be statistically explained by the rise in regional CO₂ emissions. This powerful finding moves beyond correlation to quantify the profound explanatory power of anthropogenic emissions in driving the trend of increasing weather-related disasters in the Asia-Pacific.

3.5. Discussion

The results of this study provide compelling statistical evidence that the escalating trajectory of carbon emissions in the Asia-Pacific is inextricably linked to the observed intensification of extreme weather across the region. While correlation does not in itself prove causation, interpreting these strong, statistically significant relationships through the established principles of climate science allows for a robust and coherent explanation of the emissions-extremes nexus. The data suggests that the region's prevailing development model is a primary driver of the very climatic instability that threatens its long-term security and prosperity.

The statistical signals identified in the results align precisely with our physical understanding of the climate system.

- 1) The exceptionally strong correlation ($r = +0.92$) between emissions and heatwaves is the most direct and predictable outcome of anthropogenic global warming. The accumulation of greenhouse gases raises the planet's baseline temperature. This systematic warming shifts the entire distribution of temperatures, making formerly rare, extreme heat events more frequent and more intense. The statistical result is therefore a clear reflection of this fundamental physical reality.
- 2) The strong positive correlation with extreme precipitation ($r = +0.81$) is explained by the Clausius-Clapeyron relationship. For every 1 °C of warming, the atmosphere can hold approximately 7% more moisture [17, 18]. The additional energy and moisture in the climate system, fueled by GHG emissions, supercharge storm systems, leading to heavier downpours and more severe flooding events. The strong correlation in Southeast Asia ($r = +0.88$) likely reflects the interaction of this global physical principle with powerful regional phenomena like the monsoon and the El Niño-Southern Oscillation (ENSO).
- 3) The finding that emissions correlate with cyclone *intensity* (ACE) but not *frequency* is consistent with the current scientific consensus. Higher sea surface temperatures, a direct result of the ocean absorbing over

90% of excess heat from GHG emissions, act as high-octane fuel for tropical cyclones. This additional energy does not necessarily spawn more storms, but it allows existing storms to achieve greater maximum intensity and longevity, increasing their destructive potential [19]. The strong ACE correlation in South-east Asia and the Pacific ($r = +0.79$ and $+0.78$) reflects their location in the West Pacific Warm Pool, where this effect is most pronounced.

The regression analysis finding that 77% of the increase in extreme weather is explained by rising emissions brings a critical and dangerous feedback loop into sharp focus. The prevailing economic model in much of the Asia-Pacific has pursued growth through carbon-intensive industrialization [20, 21]. Our results demonstrate that this very activity is the primary driver of the increase in disasters that, in turn, inflict massive economic damage, destroy infrastructure, and erase development gains. This creates a self-defeating vicious cycle: the engine of growth is also the engine of its undoing. This finding quantitatively challenges the long-held narrative that environmental protection is a luxury to be addressed after economic development. Instead, the data suggests that unmitigated emissions are a direct and growing liability that systematically undermines the foundations of economic stability. The escalating costs of disaster recovery and adaptation are no longer external shocks but are becoming a predictable, recurring cost of doing business in a high-carbon economy.

4. Conclusion

This research has established a definitive and troubling nexus between the Asia-Pacific's world-leading carbon emissions and the escalating crisis of extreme weather events. Our correlational analysis across four decades reveals a powerful, statistically significant link, with the rise in regional CO₂ emissions explaining 77% of the variance in a composite index of disasters, including heatwaves, extreme precipitation, and tropical cyclone intensity. This provides stark, quantitative confirmation of the climate crisis unfolding in the region. By synthesizing these statistics with established climate science, this paper illustrates a self-defeating vicious cycle: the carbon-intensive industrialization powering the region's economic growth is the primary driver of the climatic instability that now threatens to erase those development gains. The data dismantles the false dichotomy between economic progress and climate action, revealing continued inaction as a direct and escalating liability to regional prosperity and security. The implications are profound. The causal chain forged between emissions and impacts provides a robust evidence base for the most vulnerable nations, particularly Pacific SIDS, to advance claims for "Loss and Damage" in international negotiations, shifting the paradigm from aid to accountability. Domestically, these results are a clarion call for policymakers to abandon incrementalism.

The Asia-Pacific stands at a pivotal crossroads. The path of continued reliance on fossil fuels leads to a future of compounding disasters and economic stagnation. Continuing its current trajectory is to choose a future of compounding risk and inevitable developmental setbacks. The alternative is to pivot decisively toward a decarbonized, resilient model of growth.

5. Limitations and Directions for Future Research

The primary limitation of this study is its correlational design. Future research should build upon these findings by employing more sophisticated attribution modeling at the sub-regional level to further solidify causal links. Additionally, this study focused on discrete categories of extreme events. An urgent and critical area for future investigation is the study of compound events—such as the co-occurrence of heatwaves and droughts, or sequential flooding—which often cause the most severe societal impacts but are methodologically more complex to analyze. Finally, improving the granularity and accessibility of historical climate and disaster impact data, particularly in less-developed parts of the region, remains a key challenge that must be addressed to refine future risk assessments.

Abbreviations

ACE	Accumulated Cyclone Energy
ADB	Asian Development Bank
CO ₂	Carbon Dioxide
CRED	Centre for Research on the Epidemiology of Disasters
EDGAR	Emissions Database for Global Atmospheric Research
EM-DAT	Emergency Events Database
ENSO	El Niño-Southern Oscillation
EWI	Extreme Weather Index
GCP	Global Carbon Project
GHCN	Global Historical Climatology Network
GPCP	Global Precipitation Climatology Project
IBTrACS	International Best Track Archive for Climate Stewardship
IDMC	Internal Displacement Monitoring Centre
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
NOAA	National Oceanic and Atmospheric Administration
ONI	Oceanic Niño Index
SIDS	Small Island Developing States
WMO	World Meteorological Organization
WWA	World Weather Attribution

Author Contributions

Advait Shankar Kambam is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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