Research Article

Continental Variation in the Association between Climate Change Indicators and Allergic Diseases

Chloe Jung[1], Suri Gime[2]

[1]Eastchester High School, 2 Stewart Pl, Eastchester, NY 10709, United States; [2]Edward Via College of Osteopathic Medicine, Doctor of Osteopathic Medicine Program, Blacksburg, VA, 24060, United States

ABSTRACT

Global warming has emerged as a significant environmental threat with potential impacts on human health. Although the association between climate change and respiratory diseases has been studied extensively, very little focus has been placed on allergic diseases with the account for continental variation. The objective of this study is to explore the associations between indicators of global warming, mean temperature anomaly and greenhouse gas emission, and health outcomes of asthma and atopic dermatitis. Data were obtained from a worldwide health database during the years 2000 to 2020. The analysis was broken down in five continents (Asia, Africa, Europe, North America, South America). Average temperature anomaly in April and greenhouse gas emissions were selected as global warming indicators. Health outcomes included asthma disability-adjusted life years, asthma incidence, asthma prevalence, atopic dermatitis incidence, and atopic dermatitis prevalence, stratified by three age groups (10–19 years, ≥55 years, and all ages). Multiple linear regression analysis showed regional different correlation between global warming indicators and allergic disease outcomes. Strong correlations were found for prevalence rates of asthma and atopic dermatitis in Asia and in Africa, whereas Europe and North America showed more diversified associations. The effect of global warming on allergic disease might be heterogeneous between and among regions and populations. More evidence is needed to fully understand these associations better and to inform public health mitigation measures.

Keywords: Global Warming; Changing Environment; Allergic Diseases; Greenhouse Gases(GHG); Public Health Adaptation

INTRODUCTION

Climate change and the phenomenon of global warming were among the most prominent public health challenges of this century. Elevated atmospheric levels of greenhouse gases (GHG) such as carbon dioxide, methane, nitrous oxide, and fluorinated gases, have a heat-trapping effect, and strengthen the greenhouse effect, causing global changes in temperature patterns (1). These changes in the environment have been associated with multiple health effects, primarily respiratory and allergic diseases (2).

Higher temperatures and modified rainfall patterns have been linked to extended pollen seasons, increased

---

Corresponding author: Suri Gime, E-mail: ysk28@cornell.edu.

Accepted August 27, 2025
https://doi.org/10.70251/HYJR2348.351727

pollen production, and altered distribution of plants producing allergenic pollen, all leading to greater prevalence and exacerbation of atopic diseases (3). Also, there is the issue of air pollution and higher levels of greenhouse gas, which are culprits in amplifying allergens and therefore the allergic reaction (4).

Although the association between environmental factors and allergic diseases is well established, little attention has been given to how specific global warming indices, such as average temperature anomaly and greenhouse gas (GHG) emissions, are associated with the burden of allergic diseases in different world regions. Sensitivities with respect to physiology and preexisting disease make certain subpopulations such as children and elderly, more susceptible to adverse health effects.

Utilizing data from the Global Burden of Disease (GBD) database for five major continental regions (Asia, Africa, Europe, North America, and South America) from 2000 to 2020, the study evaluated average temperature anomaly for the month of April for a given year, and greenhouse gas (GHG) emissions in million metric tons of CO_2 equivalent, as possible factors influencing health outcomes (5). April was used to best capture the impact on allergic disease. The health effects were assessed through five primary indicators: disability-adjusted life years (DALYs) from asthma, asthma incidence and prevalence, and atopic dermatitis incidence and prevalence. The analysis was also completed by differential age groups (10–19 years, ≥55 years, and all ages) to identify gaps in health outcomes among the most vulnerable subpopulations.

A continental comparison is particularly important because exposure profiles (pollen taxa and seasonality, temperature anomaly patterns, GHG composition), population vulnerabilities (age distribution, comorbidities), and modifying systems (urbanization, healthcare access, and diagnostic practices) differ systematically across regions. These differences can lead to true effect heterogeneity rather than simple variation in magnitude and may even result in opposite directions of association across continents. Moreover, while previous studies have largely focused on single countries, respiratory outcomes, or single exposures, this study contributes by jointly examining asthma and atopic dermatitis, stratifying by vulnerable age groups, and comparing five continental regions over two decades. This design allows testing whether GHG explains variance that temperature anomaly does not, and whether the climate–allergy relationship differs by phenotype, age, and continent (6).

This study seeks to inform our knowledge of the intricate relationships between changing environment and the patterns of allergic disease and provide data that can inform future public health adaptations and mitigations.

METHODS AND MATERIALS

Data Source and Variable Selection

The Global Burden of Disease (GBD) study, conducted by the Institute for Health Metrics and Evaluation, provides comprehensive global health data to assess these trends. Average temperature anomaly (TAA) and greenhouse gas emissions (GHG) were used as indicators of global warming (5). TAA represents deviations from the expected historical temperature patterns of a given region and was specifically measured in April, the month typically associated with the highest incidence of seasonal allergies. GHG emissions, reported in million metric tons of CO_2 equivalent (Mt CO_2e), is an indicator of industrial activities such as the combustion of fossil fuels. These emissions include carbon dioxide, methane, nitrous oxide, and fluorinated gases, which trap heat in the atmosphere and contribute to the greenhouse effect and global warming.

To assess the impact of global warming on seasonal allergies, the following health outcomes were analyzed: asthma disability-adjusted life years (ASDALY), asthma incidence rate (ASIN), asthma prevalence rate (ASPR), atopic dermatitis incidence rate (ADIN), and atopic dermatitis prevalence rate (ADPR). Data were stratified by three age groups; 10–19 years, ≥55 years, and all ages combined, to evaluate the differential effects of global warming on vulnerable populations compared with the general population.

The use of multiple health outcome metrics was intended to provide a comprehensive assessment of disease burden from both morbidity and epidemiological perspectives. Disability-adjusted life years (DALY) quantify the overall burden of disease by calculating years of life lost due to the disability, offering an integrated measure of health outcome. Incidence rates reflect the number of new cases occurring in a defined population over a specified period, thereby capturing the dynamic risk of developing the disease. Prevalence rates, in contrast, represent the total number of existing cases at a given point in time, providing insight into the long-term disease burden and ongoing healthcare needs. By examining these distinct yet complementary measures, this study aimed to capture the full spectrum of disease impact and better elucidate potential relationships between global warming and allergic disease patterns.

A regional analysis was conducted across Asia (n = 50), Africa (n = 53), Europe (n = 45), North America (n = 26), and South America (n = 10) for cross continental comparisons. Data from 2000 to 2020 were included in the study to capture long term progression and associations between global warming indicators and allergic disease outcomes.

Statistical Analysis

All statistical analyses were conducted using GraphPad Prism (v10.1), Microsoft Excel (2024), and R version 4.3.2 in RStudio (2025 release). To explore the association between global warming indicators and allergy related health measurements in different age groups, Pearson correlation analysis was initially performed to identify the direction and strength of linear relationships (7). Multiple linear regression models were then employed to assess the combined and independent effects of predictors (8). All analyses accounted for multicollinearity and were validated using residual diagnostics.

RESULTS

Pearson R Correlation Coefficient

Contrary to the common assumption that global warming indicators would result in uniform effects on allergic disease outcomes across regions, the correlation matrices demonstrate substantial heterogeneity. In Figure 1A, the correlation matrix for Asia reveals a strong negative association between both TAA and GHG with most allergy related variables, except for ADIN in the 10–19 age group, which showed a positive correlation.

In Figure 1B, Africa displays a markedly different

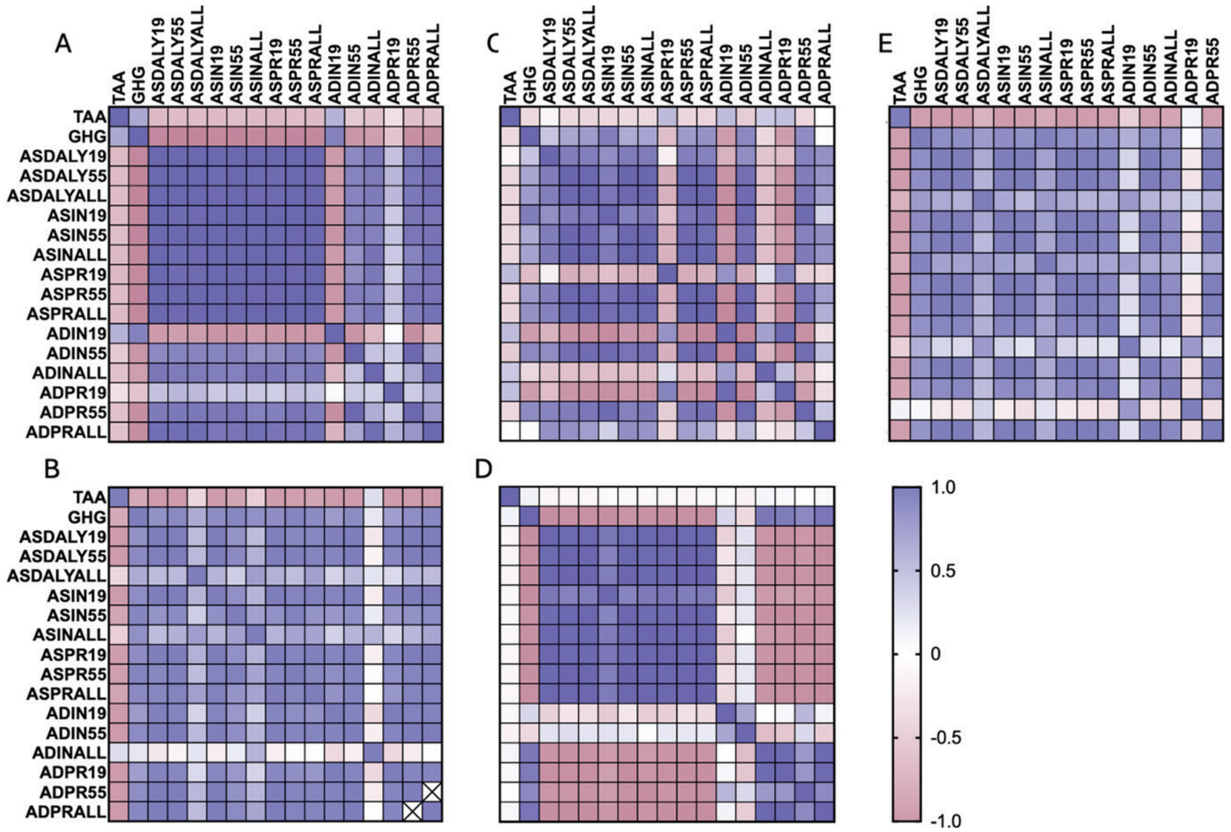

Figure 1. Correlation matrix heatmap illustrating the relationships between global warming indicators and seasonal allergy related measures across world regions. The color of each cell represents the correlation coefficient between two variables, with darker colors indicating stronger correlations. Dark purple indicates positive correlations, whereas dark pink represents negative correlations. Each panel corresponds to a different geographic region: A. Asia, B. Africa, C. Europe, D. North America, E. South America.

pattern, with strong positive correlations observed between GHG and most allergic disease indicator, while TAA generally shows negative correlations. Similar trends to Africa were observed in Figures 1C and 1E, respectively corresponding to Europe and South America, where GHG levels correlate positively with allergic outcomes, while it remains mostly negatively associated.

In contrast, Figure 1D (North America) presents a distinct pattern where correlations between TAA and allergic indicators are nearly absent. This observation may imply that improved healthcare infrastructure and access to healthcare in North America could mitigate the potential adverse health impacts associated with climate variability.

Table 1 summarizes Pearson correlation coefficients (r) between dependent variables and global warming indicators, highlighting statistically significant values with asterisks. Both TAA and GHG revealed a significant negative correlation with most allergy related outcomes across all age groups in Asia. These results suggest that improved healthcare may be offsetting the adverse effects of environmental changes. An exception is found in the 10–19 age group for ADIN, which positively correlates with both TAA ($r = 0.490$, $p < 0.05$) and GHG ($r = 0.820$, $p < 0.01$), suggesting that younger individuals may be particularly vulnerable to air quality derived environmental shifts.

Table 2 displays Pearson coefficients for Africa, showing a strong negative correlation trend between TAA and allergic outcomes and a strong positive association between GHG and most allergy measures across all ages. This contrasting result may suggest that GHG, a marker of air pollution, could have a more immediate and pronounced impact on allergic diseases than temperature variations in Africa. This consistently strong positive

Table 1. Pearson correlation coefficients (r) between dependent variables and global warming indicators in Asia

	ASDALY			ASIN			ASPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.570**	-0.552**	-0.550*	0.490*	-0.440*	-0.567**	-0.582**	-0.550*	-0.564**
GHG	-0.975**	-0.992**	-0.992**	0.820**	-0.851**	-0.950**	-0.945**	-0.988**	-0.965**

	ADIN			ADPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age
TAA	0.490*	-0.440*	-0.504*	-0.259*	-0.516*	-0.508*
GHG	0.820**	-0.851**	-0.796**	-0.480*	-0.913**	-0.912**

**P<0.05. **P < 0.01.*

Table 2. Pearson correlation coefficients (r) between dependent variables and global warming indicators in Africa

	ASDALY			ASIN			ASPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.977**	-0.976**	-0.421	-0.975**	-0.882**	-0.499*	-0.968**	-0.944**	-0.896**
GHG	0.863**	0.915**	0.661**	0.888**	0.938**	0.867**	0.892**	0.952**	0.908**

	ADIN			ADPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.982**	-0.978**	0.275	-0.976**	-0.979**	-0.974**
GHG	0.786**	0.904**	0.203	0.769**	0.889**	0.924**

**P<0.05. **P < 0.01.*

relationship between GHG and health indicators as can be seen in the prevalence rate of both allergic diseases supports the idea of a heightened allergic disease burden associated with increased emissions.

Table 3 presents Pearson correlation results for Europe. Compared to Africa, Europe shows generally weak yet statistically significant positive correlations between GHG and most allergy outcomes. Noteworthy is the reversal of correlations in atopic dermatitis (ADIN, ADPR) across age groups: the 10–19-year group shows a negative correlation, while individuals aged ≥55 show significant positive correlations. This finding suggests older Europeans may be more susceptible to the health effects of rising GHG levels.

Table 4 presents the Pearson correlation coefficients between dependent variables and global warming indicators in North America. Overall, correlations between TAA and health outcomes were weak and largely non-significant across most variables. However, indicators of atopic dermatitis, including both ADIN and ADPR showed a statistically significant positive correlation with TAA across all age groups.

In contrast, GHG demonstrated consistently strong negative correlations with asthma related health outcomes (ASDALY, ASIN, ASPR) across all age groups. On the other hand, ADIN (r = 0.884, $p < 0.01$) and ADPR (r = 0.895, $p < 0.01$) both exhibited a strong positive correlation with GHG. Similarly, ADPR also exhibited a statistically significant positive correlation with GHG across all age groups. Strong positive correlation scores of AD (Atopic Dermatitis) measures (ADIN and ADPR) suggests that AD is more strongly associated with GHG changes.

Table 5 presents the Pearson correlation coefficients between dependent variables and global warming indicators in South America. The results reveal a pattern

Table 3. Pearson correlation coefficients (r) between dependent variables and global warming indicators in Europe

	ASDALY			ASIN			ASPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.084	-0.326	-0.341	-0.330	-0.315	-0.326	0.440*	-0.348	-0.354
GHG	0.373	0.573**	0.640**	0.841**	0.538*	0.585**	-0.542*	0.646**	0.708**

	ADIN			ADPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age
TAA	0.425	-0.413	0.339	0.414	-0.331	-0.031
GHG	-0.794**	0.769**	-0.328	-0.798**	0.754**	0.016

**P<0.05. **P < 0.01.*

Table 4. Pearson correlation coefficients (r) between dependent variables and global warming indicators in North America

	ASDALY			ASIN			ASPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.098	-0.109	-0.096	-0.059	-0.075	-0.079	-0.083*	-0.086	-0.080
GHG	-0.925**	-0.902**	-0.910**	-0.919**	-0.874**	-0.888**	-0.921**	-0.904**	-0.907**

	ADIN			ADPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.066	-0.122**	0.079	0.052**	0.006**	0.055**
GHG	0.262	-0.317	0.884**	0.855**	0.771**	0.895**

**P<0.05. **P < 0.01.*

similar to that observed in Africa, where greenhouse gas emissions (GHG) were consistently and significantly negatively correlated with allergic disease indicators across all age groups.

All statistically significant associations indicated negative correlations, suggesting that higher GHG levels may be associated with reduced reported rates of allergy-related outcomes in this region. This unexpected trend suggest presence of potential confounding factors and highlights the need for further investigation.

Multiple Linear Regression Coefficient

Table 6 summarizes the results of the multiple linear regression analysis assessing the association between global warming indicators and allergic disease prevalence in Asia across all age groups. Greenhouse gas emissions (GHG) were found to be significantly and negatively associated with both asthma prevalence ($\beta = -0.0757$, $p < 0.01$) and atopic dermatitis prevalence ($\beta = -0.0022$, $p < 0.01$). In contrast, temperature anomaly (TAA) did not show statistically significant associations with either outcome, although a negative trend was observed for asthma prevalence ($\beta = -14.3299$).

The regression models demonstrated excellent fit, with R^2 values of 0.9321 for asthma prevalence and 0.8311 for atopic dermatitis prevalence, indicating that the selected variables accounted for a substantial proportion of the variance in disease prevalence across all age groups during the study period.

These findings suggest that GHG emissions were more strongly associated with allergic disease outcomes than temperature anomaly in Asia, though the unexpected inverse relationship suggests the need for further research to explore potential confounding factors or regional healthcare availability.

Table 7 summarizes the results of the multiple linear regression analysis assessing the association between global warming indicators and allergic disease prevalence in Africa across all age groups. Greenhouse gas emissions (GHG) were found to be significantly and

Table 5. Pearson correlation coefficients (r) between dependent variables and global warming indicators in South America

	ASDALY			ASIN			ASPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.463*	-0.614**	-0.649**	-0.134	-0.600**	-0.675**	-0.317	-0.602**	-0.658**
GHG	-0.950**	-0.970**	-0.963**	-0.756**	-0.976**	-0.947**	-0.845**	-0.974**	-0.960**

	ADIN			ADPR		
Age Group	10-19	55+	All Age	10-19	55+	All Age
TAA	-0.644	0.094	-0.643	-0.673	0.431	-0.660
GHG	-0.925**	-0.482*	-0.945**	-0.889**	0.114	-0.943**

**P<0.05. **P < 0.01.*

Table 6. Regression coefficients between dependent variables and Global Warming Indicator for the multiple linear regression model in Asia

Dependent Variable		**Global Warming Indicators**	
		Green House Gas Emission (MtCO2e)	**Temperature Anomaly in the month of April**
Asthma Prevalence Rate (per 100,000 population) (*R^2: 0.9321)*	β Coefficient	-0.0757 **	-14.3299
Atopic Dermatitis Prevalence Rate (per 100,000 population) (*R^2: 0.8311)*	β Coefficient	-0.0022**	0.1039

**P<0.05. **P < 0.01.*

positively associated with both asthma prevalence (β = 2.7829, $p < 0.01$) and atopic dermatitis prevalence (β = 0.2912, $p < 0.05$). In contrast, temperature anomaly (TAA) demonstrated positive regression coefficients for both outcomes (asthma: β = 28.1160; atopic dermatitis: β = 2.5589), but these associations were not statistically significant.

The regression models showed excellent fit, with R^2 values of 0.8937 for asthma prevalence and 0.9577 for atopic dermatitis prevalence, indicating that the selected variables accounted for a substantial proportion of the variance in disease prevalence across all age groups.

These findings suggest that, in Africa, GHG emissions had a stronger and statistically significant association with allergic disease prevalence than temperature anomaly. The positive direction of all regression coefficients may reflect a potential cumulative environmental burden, although the lack of statistical significance for TAA warrants cautious interpretation and highlights the need for further investigation.

Table 8 summarizes the results of the multiple linear regression analysis assessing the association between global warming indicators and allergic disease prevalence in Europe across all age groups. Greenhouse gas emissions (GHG) were significantly and positively associated with both asthma prevalence (β = 1.1209, $p < 0.01$) and atopic dermatitis prevalence (β = 0.1005, $p < 0.05$).

In contrast, temperature anomaly (TAA) demonstrated negative regression coefficients for both outcomes (asthma: β = -129.3899; atopic dermatitis: β = -0.9689), but neither association reached statistical significance. The model for asthma prevalence showed good fit (R^2 = 0.8518), whereas the model for atopic dermatitis prevalence explained very little of the variability (R^2 = 0.001), indicating poor predictive capacity.

These findings suggest that in Europe, GHG emissions had a stronger and statistically significant association with allergic disease prevalence compared to temperature anomaly. The very low explanatory power for atopic dermatitis highlights potential data variability or unmeasured confounding factors that warrant further investigation.

Table 7. Regression coefficients between dependent variables and Global Warming Indicator for the multiple linear regression model in Africa

Dependent Variable		**Global Warming Indicators**	
		Green House Gas Emission (MtCO2e)	**Temperature Anomaly in the month of April**
Asthma Prevalence Rate (per 100,000 population) (*R^2: 0.8937)*	β Coefficient	2.7829**	28.1160
Atopic Dermatitis Prevalence Rate (per 100,000 population) (*R^2: 0.9577)*	β Coefficient	0.2912*	2.5589

**P<0.05. **P < 0.01.*

Table 8. Regression coefficients between dependent variables and Global Warming Indicator for the multiple linear regression model in Europe

Dependent Variable		**Global Warming Indicators**	
		Green House Gas Emission (MtCO2e)	**Temperature Anomaly in the month of April**
Asthma Prevalence Rate (per 100,000 population) (*R^2: 0.8518)*	β Coefficient	1.1209**	-129.3899
Atopic Dermatitis Prevalence Rate (per 100,000 population) (*R^2: 0.001)*	β Coefficient	0.1005*	-0.9689

**P<0.05. **P < 0.01.*

Table 9 shows the results of the multiple linear regression analysis assessing the association between global warming indicators and allergic disease prevalence in North America across all age groups. Greenhouse gas emissions (GHG) were significantly and negatively associated with asthma prevalence (β = -2.2583, $p < 0.01$), while showing a small but statistically significant positive association with atopic dermatitis prevalence (β = 0.1023, $p < 0.05$).

Temperature anomaly (TAA) demonstrated non-significant associations with both outcomes (asthma: β = 4.4537; atopic dermatitis: β = -1.5805). The regression models showed strong fit, with R^2 values of 0.8234 for asthma prevalence and 0.8025 for atopic dermatitis prevalence, indicating that the selected variables explained a substantial proportion of the variance in disease prevalence across all age groups.

These findings suggest a complex pattern in North America, where higher GHG emissions were associated with reduced asthma prevalence but increased atopic dermatitis prevalence. The lack of statistically significant associations for TAA highlights the potential role of other environmental or healthcare factors in modifying the relationship between global warming indicators and allergic disease outcomes.

Table 10 summarizes the results of the multiple linear regression analysis assessing the association between global warming indicators and allergic disease prevalence in South America across all age groups. Greenhouse gas emissions (GHG) were significantly and positively associated with both asthma prevalence (β = 1.7638, $p < 0.01$) and atopic dermatitis prevalence (β = 0.2737, $p < 0.05$).

Temperature anomaly (TAA) demonstrated strong negative regression coefficients for both asthma prevalence (β = -437.6198) and atopic dermatitis prevalence (β = -74.6990), although these associations were not statistically significant. The regression models showed excellent fit, with R^2 values of 0.9959 for asthma prevalence and 0.9285 for atopic dermatitis prevalence, indicating that the selected variables accounted for a substantial proportion of the variance in disease prevalence across all age groups.

These findings suggest that in South America, GHG

Table 9. Regression coefficients between dependent variables and Global Warming Indicator for the multiple linear regression model in North America

Dependent Variable		**Global Warming Indicators**	
		Green House Gas Emission (MtCO2e)	**Temperature Anomaly in the month of April**
Asthma Prevalence Rate (per 100,000 population) (*R^2: 0.8234)*	β Coefficient	-2.2583**	4.4537
Atopic Dermatitis Prevalence Rate (per 100,000 population) (*R^2: 0.8025)*	β Coefficient	0.1023*	-1.5805

**P<0.05. **P < 0.01.*

Table 10. Regression coefficients between dependent variables and Global Warming Indicator for the multiple linear regression model in South America

Dependent Variable		**Global Warming Indicators**	
		Green House Gas Emission (MtCO2e)	**Temperature Anomaly in the month of April**
Asthma Prevalence Rate (per 100,000 population) (*R^2: 0.9959)*	β Coefficient	1.7638**	-437.6198
Atopic Dermatitis Prevalence Rate (per 100,000 population) (*R^2: 0.9285)*	β Coefficient	0.2737*	-74.6990

**P<0.05. **P < 0.01.*

emissions were more strongly and consistently associated with allergic disease prevalence than temperature anomaly. The high R^2 values reflect excellent model performance; however, the large negative coefficients for TAA without statistical significance warrant cautious interpretation and highlight the need for further investigation into potential confounding factors.

DISCUSSION

The study investigated the relationship between greenhouse gas emissions (GHG) and temperature anomaly (TAA) and the prevalence of allergic diseases over a 20-year period involving five large world regions. The research showed high regional heterogeneity, and GHG was generally found to be significantly and more strongly related to the outcomes of allergic diseases when compared to TAA. GHG was found to be directly related to the prevalence of allergic diseases for Africa, Europe, and South America but was inversely related to the prevalence of asthma for North America and Asia.

The uniformly non-significant relationships between TAA in all regions, however, indicate that short-term temperature variation might be less directly influential than the cumulative environmental impact expressed through GHG emissions. This is consistent with previous studies showing that ambient changes in temperature might be less important relative to air quality and pollutant exposures for the pathophysiology of allergic diseases.

When compared with the multiple linear regression analysis results, pearson correlation values show a notably different trend. This is due to the Pearson correlation being a bivariate analysis, which is limited to identifying weak relationships between two variables while the multiple linear regression produces a multivariant comparison across number of variables, fitting better for the purpose and characteristics of the study. Multiple linear regression model best captured positive relationship between GHG emissions and measures of atopic dermatitis indicating that this multivariate model was effective in removing confounding effects that may have hidden true relationship in a simple correlation analysis. Furthermore, multiple linear regression model's capability to predict nonlinear relationship offered a stronger insight that translated the complicated relationship between global warming indicators and allergic disease indicators.

Findings from the study suggest that exposure to air pollution caused by GHG emissions may work as a chronic irritant and inflammatory stimulus, especially for vulnerable age groups such as children and the elderly. Different direction of associations seen between atopic dermatitis and asthma in some continents, especially in North America, suggests a room for compounded interactions between environmental factors, health care availability and infrastructure available.

Beyond biological plausibility, several structural and contextual factors may explain why findings differ across continents. Europe and North America benefit from stronger surveillance and pollen monitoring systems, which improve exposure measurement and disease reporting, while many countries in Africa and Asia lack routine monitoring, increasing the chance of underestimation (9). Underdiagnosis and underreporting of asthma and atopic dermatitis are also more common in low- and middle-income regions, leading to artificially lower prevalence estimates despite a high symptom burden (10). Levels of urbanization further contribute to rapid urban growth in Africa and Asia, which increases exposure to traffic-related air pollution and built-environment heat while also limiting equitable access to specialty care, whereas Europe and North America already have mature urban infrastructures and broader health-care availability (11). Health-system capacity and diagnostic criteria differ as well, with variable case definitions for atopic dermatitis and limited access to trained specialists in resource-limited settings, adding heterogeneity to outcome measures. Taken together, these differences suggest that regional heterogeneity in our results is not only biological but also shaped by disparities in monitoring, reporting, and urban development. Recognizing these limitations highlights the importance of conducting continent-specific analyses instead of pooling data into a single global estimate.

CONCLUSION

This study provides a comprehensive evaluation of the relationship between global warming indicators and allergic disease prevalence across five major continents. Multiple linear regression analysis demonstrates substantial regional variability, with greenhouse gas emissions (GHG) consistently showing stronger associations with allergic disease outcomes than temperature anomaly (TAA). While the ecological design of the study poses a limitation in fully capturing causal inference, the multivariate regression models offer valuable insights into potential relationships that may be obscured in simple Pearson regression correlation analyses.

Positive association observed between GHG emissions and atopic dermatitis prevalence across all age groups highlights the significance air pollution quality carries in developing allergic disease. This highlights the importance of considering environmental health outcomes in shaping public health policies at country and global level. As global temperature and industrial emissions continue to rise, understanding these complex interactions between environmental changes and human health will be vital in developing effective prevention strategies to reduce the burden of allergic diseases worldwide.

There are some limitations before interpreting the findings of this study. First, ecological study design is not ideal for making causal inference at individual level, due to aggregated regional data analysis that overlooks variations and local differences within each country. Unadjusted associations, including the inverse association between GHG emissions and allergic disease prevalence in specific regions, could be due to confounding by factors not available for analysis such as access to healthcare, degree of urbanization, or level of industrial development, diagnostic patterns or socioeconomic status.

Second, the temperature anomaly factor in our study represents the short monthly change in the month of April, and therefore, may not capture the longer-term climate trends, or cumulative exposure that might be related to chronic disease development. In addition, other potentially relevant environmental variables such as pollen counts, air quality indices, or particulate matter were unavailable for more detailed indications of global warming.

Last, inconsistencies and missing data between countries and years could have resulted in bias or influenced the precision of the model estimates. Limitations notwithstanding, our study provides useful information on putative cross-national relationships between environmental factors and allergic disease prevalence and highlights the need for more longitudinal, individual level local studies to better address these complex relationships.

From a public health perspective, practical recommendations emerge from our findings. Standardized monitoring of aeroallergens and air pollutants across regions is critical to improve comparability and reduce measurement error. Interdisciplinary data collection that integrates meteorology, environmental science, and clinical surveillance can provide a more accurate understanding of exposure–outcome dynamics. Furthermore, continent-specific health policies that account for regional vulnerabilities—such as underdiagnosis in Africa/Asia or rapid urbanization pressures—will be necessary to design effective prevention and mitigation strategies.

Future research should also address key gaps. Longitudinal and cohort-based studies are needed to clarify causal pathways at the individual level. Multi-exposure models that incorporate pollen counts, particulate matter, and climate anomalies simultaneously could help disentangle co-occurring drivers of allergic disease. In addition, greater focus should be placed on vulnerable subgroups, including children, adolescents, and the elderly, to better understand life-course susceptibility to climate–allergy interactions. Expanding such research will be essential to inform targeted interventions and global adaptation strategies.

REFERENCES

1. Filonchyk M, Peterson MP, Zhang L, Hurynovich V & He Y. Greenhouse gases emissions and global climate change: Examining the influence of CO_2, CH_4, and N_2O. *Science of the Total Environment*. 2024; 935 (935): 173359–173359. https://doi.org/10.1016/j.scitotenv.2024.173359
2. Huang C, Barnett AG, Xu Z, Chu C, *et al*. Managing the Health Effects of Temperature in Response to Climate Change: Challenges Ahead. *Environmental Health Perspectives*. 2013; 121 (4): 415–419. https://doi.org/10.1289/ehp.1206025
3. Eguiluz-Gracia I, Mathioudakis AG, Bartel S, Vijverberg SJH, *et al*. The need for clean air: The way air pollution and climate change affect allergic rhinitis and asthma. *Allergy*. 2020; 75 (9). https://doi.org/10.1111/all.14177
4. Zeynep Çelebi Sözener, Treffeisen ER, Betül Özdel Öztürk & Schneider LC. Global warming and implications for epithelial barrier disruption and respiratory and dermatologic allergic diseases. *Journal of Allergy and Clinical Immunology*. 2023; 152 (5): 1033–1046. https://doi.org/10.1016/j.jaci.2023.09.001
5. Institute for Health Metrics and Evaluation, University of Washington. (2022). Global Burden of Disease (GBD). Institute for Health Metrics and Evaluation. Available from: https://vizhub.healthdata.org/gbd-results (accessed on 2025-06-21)
6. Caraballo L, Zakzuk J, Lee BW, Acevedo N, *et al*. Particularities of allergy in the Tropics. *World Allergy Organization Journal*. 2016; 9: 20. https://doi.org/10.1186/s40413-016-0110-7
7. Holton JR & Hakim GJ. The General Circulation.

ScienceDirect; Elsevier. 2013. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/temperature-anomaly

8. Lenhard W. Online-Calculator for testing correlations: Psychometrica. 2017. Www.psychometrica.de. https://www.psychometrica.de/correlation.html
9. Rabe APJ, Loke WJ, Gurjar K, Brackley A & Lucero-Prisno III, DE. Global Burden of Asthma and Patterns of Distribution in Key Clinical Subgroups: Nasal Polyps, Allergic Rhinitis, Severe Asthma, and Eosinophilic Asthma. SSRN Electronic Journal. 2022. https://doi.org/10.2139/ssrn.4129272
10. Desalu OO, Adeoti AO, Ojuawo OB, Aladesanmi AO, *et al*. Urban–Rural Differences in the Epidemiology of Asthma and Allergies in Nigeria: A Population-Based Study. *Journal of Asthma and Allergy*. 2021; 14: 1389–1397. https://doi.org/10.2147/JAA.S333133
11. Rodriguez A, Brickley E, Rodrigues L, Normansell RA, *et al*. Urbanisation and asthma in low-income and middle-income countries: a systematic review of the urban–rural differences in asthma prevalence. *Thorax*. 2019; 74 (11): 1020–1030. https://doi.org/10.1136/thoraxjnl-2018-211793