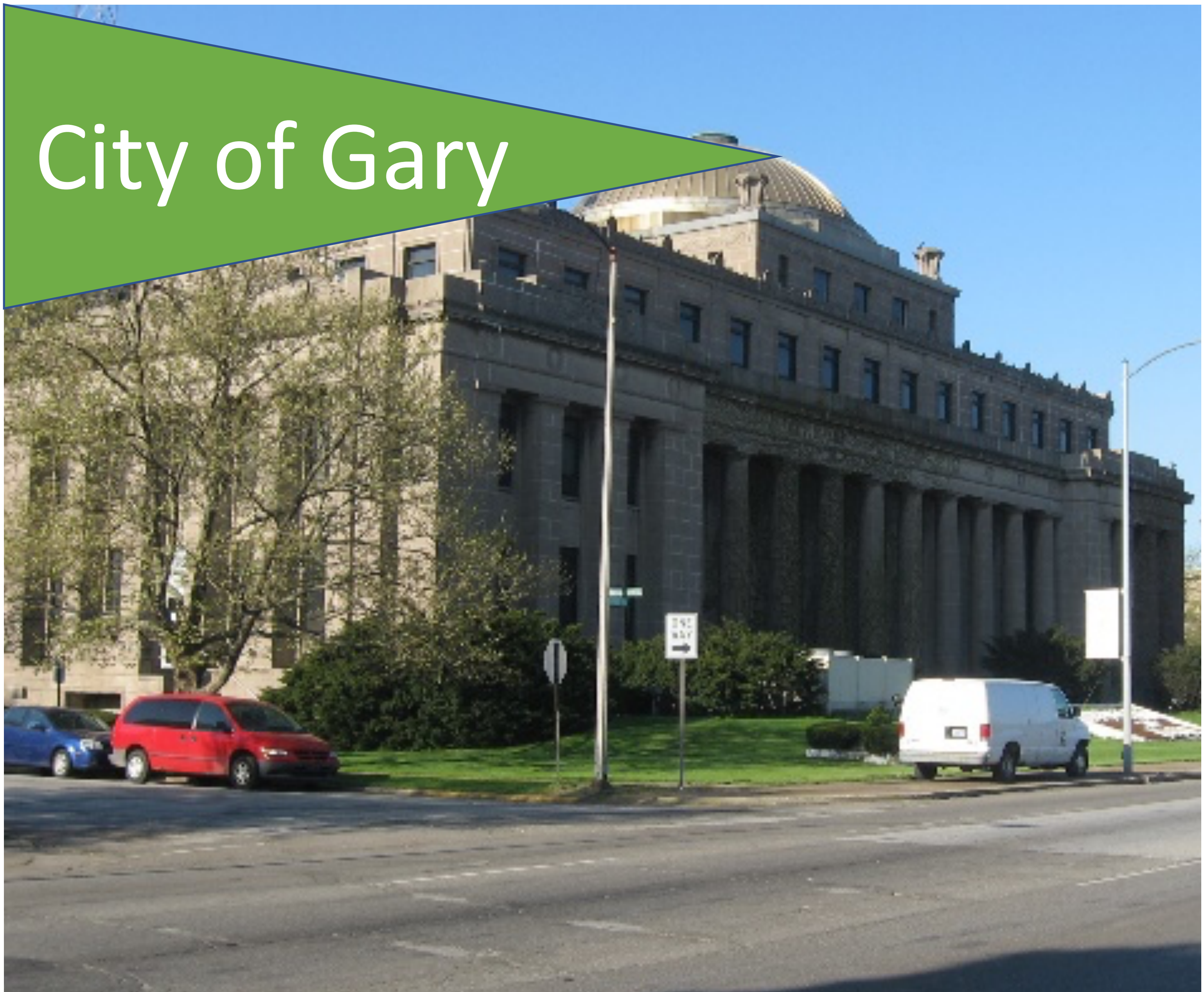
City of Gary



Climate Trends Primer

INDIANA UNIVERSITY
ENVIRONMENTAL RESILIENCE INSTITUTE

PREPARED BY CITY OF GARY DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENTAL AFFAIRS

Executive Summary

The City of Gary was established in 1906 as an industrial community but restructuring of industry led to population loss of 55% since its peak in the 1960s, leading to a large part of the urban area becoming deserted, with societal challenges like poverty and the formation of disadvantaged neighborhoods. Making it part of the Environmental Justice Community that ensures that every community receives equal protection against environmental and health risks, as well as equitable participation in decision-making processes, to maintain a healthy environment conducive to live, learn, and work.

In 2019, Gary finalized a comprehensive climate action plan that encompassed a community-wide and local government greenhouse gas inventory for the year 2017. The findings revealed that the community contributed 12,555,294 metric tons of CO_2 equivalent (MT CO_2e), while City operations accounted for 93,937 MT CO_2e. One significant consequence of these emissions was the deterioration in air quality, as the City experienced a notable percentage (>5%) of days surpassing the air quality standards for fine particulate matter (PM 2.5) (Gary Climate Action Plan).

Currently, the City of Gary is actively engaged in developing a climate resilience program with the aim of devising effective strategies to address the consequences of climate change. A crucial component of this initiative is the climate primer, which serves as the fundamental building block. This primer serves as a succinct and informative introduction or overview of the climate system, climate change, and associated subjects. Its purpose is to provide the city with the essential knowledge and key concepts required to comprehend the historical, present, and projected climate changes, as well as their impacts on the City. Additionally, the ongoing natural resource vulnerability assessment will serve as a valuable addition to this project.

People around the world are experiencing changing conditions that affect their daily lives. Many changes are due to human-caused climate change, resulting from combustion of fossil fuels and deforestation. Climate change is a global problem, yet the impacts and opportunities for action are local. As climate change accelerates with continued greenhouse gas emissions, local communities will need to be prepared for impacts and take action to protect people and the natural resources they depend on. Like other parts of the U.S., the City of Gary is experiencing rapid change in climate, and people are seeking strategies to increase safety, wellness, and resilience.

In the City of Gary, residents report changes in severe storms, extreme events like heat waves, timing of the seasons, water availability, and plants and wildlife. All these changes can affect peoples' health, culture, and livelihoods. Local infrastructure such as roads and bridges are also at risk from severe heat, storms, and flooding. Many changes are already occurring, and many more are expected to occur in the future.

If global action to greatly reduce greenhouse gas emissions is taken quickly, the long-term severity of climate change will be reduced, and local strategies to adapt will be more successful. In the near term, because of long-lasting greenhouse gases already emitted, drastic change will continue over the next few decades. Local action and planning to reduce the impacts of climate change are needed.

This climate change primer provides information on the expected trends and impacts specific to the City of Gary (Figure A1-1). Understanding climate change trends and impacts is the first step in identifying climate related risks and vulnerabilities. The next step will be to develop strategies that build overall resilience for both the people and natural resources of Gary.

Climate Trends Snapshot – City of Gary

	HISTORICAL TRENDS (1961–1990)	MID-CENTURY PROJECTIONS (2040–2069)	LATE-CENTURY PROJECTIONS (2070–2099)	LATE-CENTURY PROJECTIONS *with reduced emissions*
Average annual temperature	59.9° F	↑ 62.8° F to 72.4° F	↑ 63.4° F to 74.1° F	↑ 61.2° F to 70.4° F
Maximum temperature	59.9° F	↑ 62.8° F to 72.4° F	↑ 63.4° F to 74.1° F	↑ 61.2° F to 70.4° F
Minimum temperature	39° F	↑ 41.1° F to 51.6° F	↑ 43.9° F to 55.9° F	↑ 41.6° F to 50.1° F
Number of days per year above 90° F	15.5	↑ 15.6 to 111.9	↑ 27.6 to 138.4	↑ 16.2 to 102.4
Days per year with precipitation over 1 inch	4.3	↓ 0.7 to 12.3	↓ 0.6 to 13.4	↓ 0.4 to 11.2

Figure A1-1. Summary of climate trends expected for the City of Gary

Climate change data and models

The Earth's climate is regulated by a layer of gases commonly referred to as greenhouse gases for their role in trapping heat and keeping the earth at a livable temperature. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapor (H_2O). CO_2 plays an especially large role due to its long-lasting nature and amount compared to other gases. The atmospheric concentration of CO_2has risen from 280 to more than 417.06 parts per million (ppm) (*Climate Change: Atmospheric Carbon Dioxide*, 2022) in the past century, driven largely by the burning of fossil fuel, deforestation, and other human activity.

Information from ice cores allows us a glimpse into CO_2 levels over hundreds of thousands of years. This data shows us that CO_2 has fluctuated between about 175 and 300 ppm over the last 800,000 years and the current level is far above anything detected in that time period. As CO_2 levels changed in the past, changes in temperature tracked closely and we can expect this relationship to hold in the future as CO_2 and other greenhouse gases continue to increase.

For over a century, we have known that increases in the concentration of greenhouse gases in the atmosphere result in warmer temperatures. Long-term tracking data from weather stations and other research support this expected trend. Traditional knowledge from indigenous communities around the globe also indicates that there has been substantial change in conditions over time, especially since the end of the last ice age.

In order to look at projected future climate, we use computer models based on our understanding of the Earth's climate. The Intergovernmental Panel on Climate Change (IPCC), which is made up of thousands of leading scientists from around the world, has created a suite of 25+ global climate models (GCMs) from different institutions with which to predict future trends.

The IPCC models were created independently and vary substantially in their output. Yet most of the uncertainty in future conditions comes not from the models themselves, but from estimating how much action will be taken to reduce greenhouse gas emissions in the future. The different possible greenhouse gas concentrations (called Regional Concentration Pathways, or RCPs), depend on whether the international community cooperates on reducing emissions.

In this report, we provide projections based on a lower emissions pathway where emissions are greatly reduced (RCP 4.5) and a higher emissions pathway where emissions are only slightly reduced (RCP 8.5) and that is similar to the current global trajectory.

A note about uncertainty

All models have uncertainty because complex processes are simplified, and assumptions are made about how the Earth's processes work. Therefore, different models show different trends in future climate. How much they agree or disagree with each other gives us information about uncertainty. The uncertainty is similar to other types of models that we use every day to make decisions about the future, including economic models, population growth models, and ecological system models.

Much of the data on future trends in this report are compiled from an "ensemble" or average across many GCMs, which have been adjusted or "downscaled" from the global scale (coarse) to local scales (fine) using climatological data that reflects variation across the local landscape. When ensembles are used, it is important to understand the range of variation among the different models, as it can be quite great. In general, precipitation projections are associated with higher uncertainty (more variation among models) while temperature projections are associated with lower uncertainty (more agreement among models). Also, short to medium-term projections have lower uncertainty than long-term projections.

Global Trends

Global climate is changing quickly compared to past climate change throughout the Earth's history. Larger storms and severe heat waves increased in both frequency and severity across most of the world (Wuebbles et al., 2017).

The hottest year on record was 2016 (Figure A1-2). The average global temperature for 2016 was 1.7° F (about 1° C) above the 20th century average (Wuebbles et al., 2017). The last few years have also seen record-breaking, climate-related weather extremes. In the U.S., there were 18 weather- and climate-related events that cost more than $1 billion each in 2022, making it the third largest total on record ($165 billion) since 1980 (National Centers for Environmental Information, 2023).

Models project continued average global warming of 5.0° to 10.2° F (2.8° to 5.7° C) by the end of this century and continued warming for the next two centuries if emissions continue to increase (Figure A1-3) (Wuebbles et al., 2017). Because higher latitudes (closer to the poles) warm faster than areas closer to the equator, the United States is expected to warm significantly more than the global average.

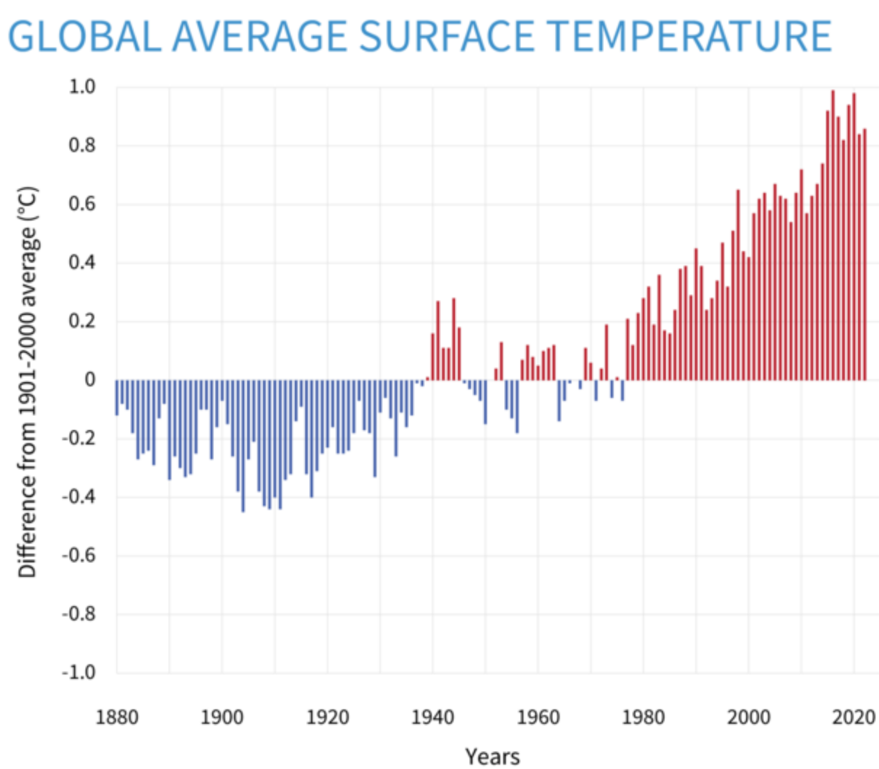


Figure A1-2. Yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years (*Climate Change: Global Temperature*, 2023).

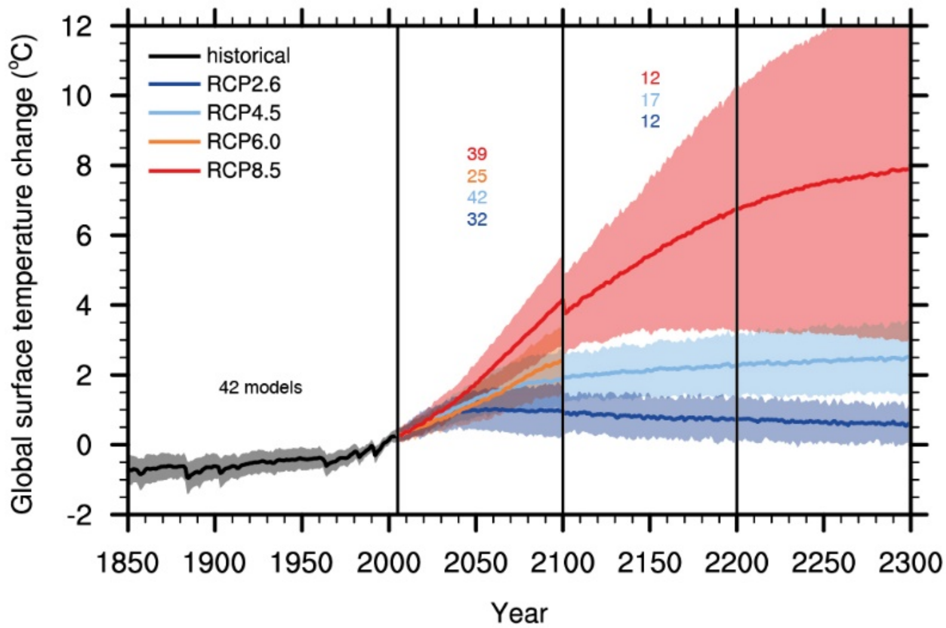


Figure A1-3. Global average surface temperature projections relative to 1986-2005. In this report, we provide projections based on a lower emissions pathway where emissions are greatly reduced (RCP 4.5) and a higher emissions pathway where emissions level off (RCP 8.5) (Schmittner, 2018).

Indiana State Trend

Temperature

Since 1895, Indiana has seen an average temperature increase of approximately 1.2° F, or an average of 0.1° F per decade. However, since 1960, the average temperature increase is approximately 0.4° F, showing an increase in climate change's effects over time. By 2050, temperatures are projected to increase between 5-6° F under the medium and high emissions scenarios, respectively. By the end of the century, average temperatures are expected to be 6 to 10° F higher than the historical average (Widhalm et al., 2018).

Similarly, maximum temperatures have increased decade-on-decade as well, with a marked increase from 1960 to present. Maximum temperatures from 1960 to 2016 have increased by an average of 0.3° F per decade; from 1895 to 2016, maximum winter and spring temperatures have increased by an average of 0.1° F per decade.

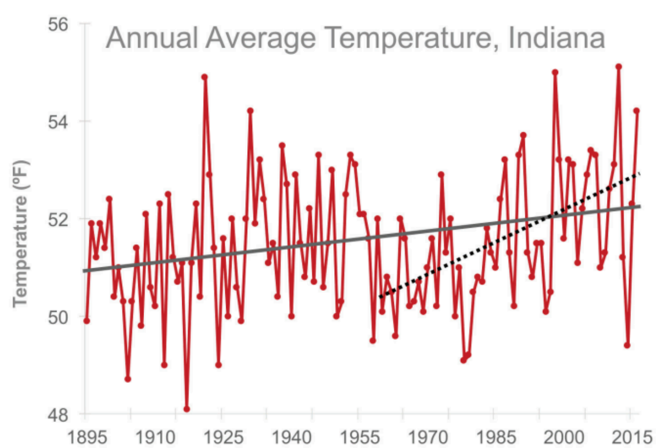


Figure A1-4. Statewide annual average temperature for Indiana from 1895 to 2016 is shown in red. The black solid line shows the increasing trend in annual temperature (0.1°F/decade) for the period from 1895 to 2016. The black dotted line shows the temperature trend since 1960 (0.4°F/decade). Image from Widhalm et al. (2018).

Extreme cold days (where the minimum temperature was below 5° F) and frost days have decreased from 1960 to 2016 by 8 and 9 days respectively. The northern third of Indiana is expected to experience the most significant increase, from an average of 13 per year to only six by 2050.

While there has not been an increase in extreme heat days (defined as days where the maximum temperature is over 95° F) from 1960 to 2016, they are projected to increase significantly in the future, from seven per year (present) to between 38 to 51 days per year.

Indiana Temperature Trends (1895 to 2016)

Variable	Winter	Spring	Summer	Fall	Annual
Tmax	0.1ºF	0.1ºF	- 1ºF	0ºF	0ºF
Tavg	0.1ºF	0.2ºF	0ºF	0.1ºF	0.1ºF
Tmin	0.2ºF	0.2ºF	0.1ºF	0.1ºF	0.2ºF

Units = ºF per decade

Indiana Temperature Trends (1960 to 2016)

Variable	Winter	Spring	Summer	Fall	Annual
Tmax	0.5ºF	0.6ºF	0.1ºF	0.2ºF	0.3ºF
Tavg	0.7ºF	0.5ºF	0.3ºF	0.2ºF	0.4ºF
Tmin	0.8ºF	0.5ºF	0.5ºF	0.3ºF	0.5ºF

Units = ºF per decade

Figure A1-5. Annual and seasonal temperature trends for Indiana from 1985 to 2016 (top) and from 1960 to 2016 (bottom). Both tables show maximum temperature (Tmax), average temperature (Tavg), and minimum temperature (Tmin). Image from Widhalm et al. (2018).

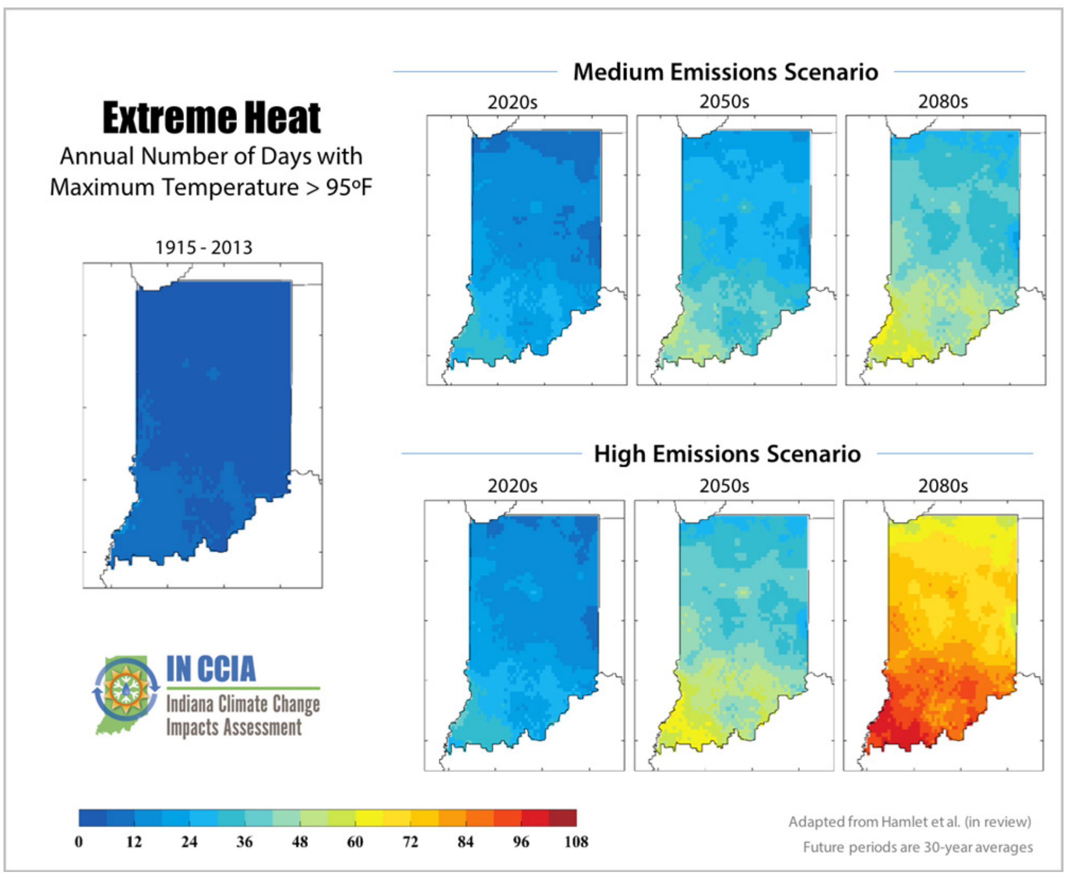


Figure A1-6. Maps showing the annual number of extreme heat days (maximum temperatures above 95°F) Image from Purdue University (n.d.).

Indiana’s frost-free season has increased by nine days since 1895. By the middle of the century, the number of frost-free days is projected to increase by between 3.5 and 4.5 weeks.

Annual precipitation in Indiana has also increased significantly since 1895. Average annual precipitation has increased by 5.6 inches, and different regions of the state have seen different amounts of increase. In the future, rainfall is expected to increase by approximately 6-8%, depending on the emissions scenario. This increase is not expected to fall evenly throughout the year- multiple climate models suggest a high likelihood of more precipitation during the winter and spring months, with less certainty about changes in precipitation during the summer and fall.

Indiana’s risk of drought conditions in the future is also worsening. The frequency of drought conditions is expected to increase, particularly during the later parts of the growing season. (Cherkauer et al., 2021)

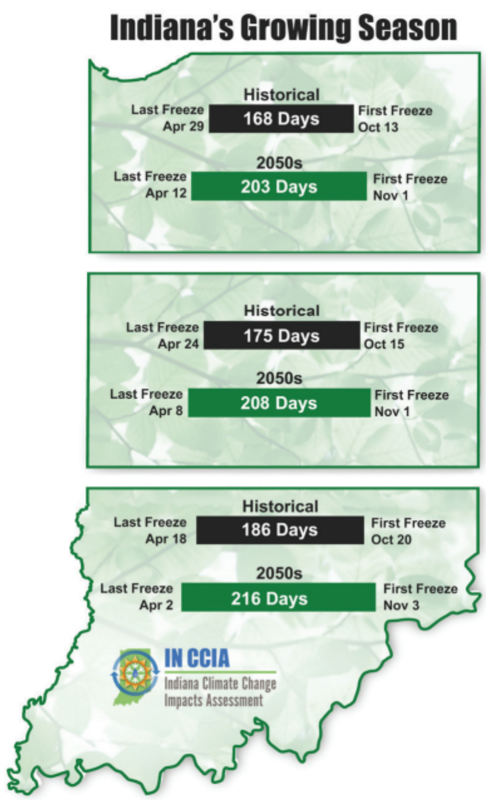


Figure A1-7. Growing season length and average first/last freeze dates for northern, central, and southern Indiana. “Historical” is the average for the period 1915 to 2013. For future projections, “2050s” represents the average of the 30-year period from 2041 to 2070 for the high emissions scenario. Image from Widhalm et al. (2018).

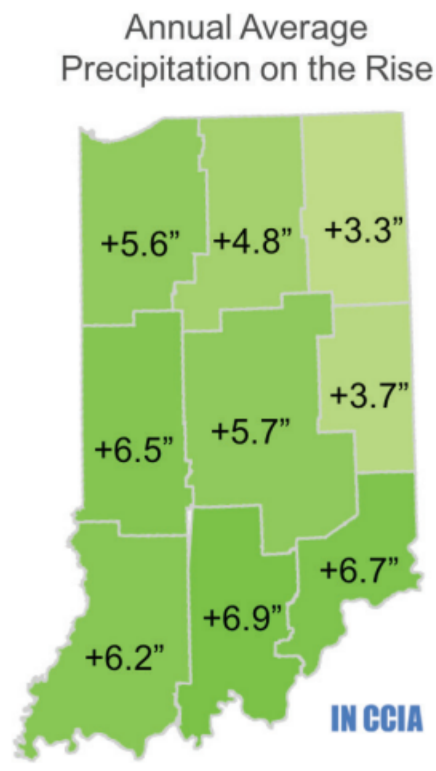


Figure A1-8. Increase in annual precipitation for Indiana’s nine climate divisions, based on a linear trend, from 1985 to 2016. Image from Widhalm et al. (2018).

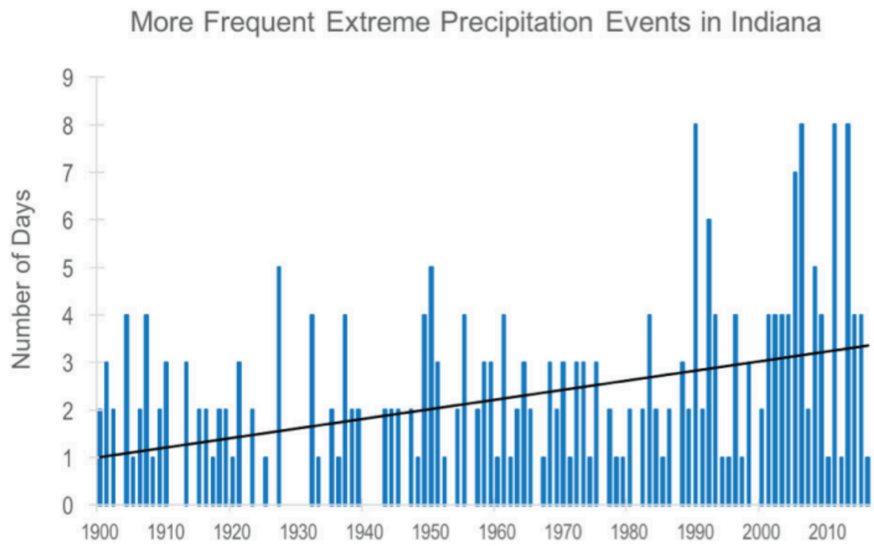


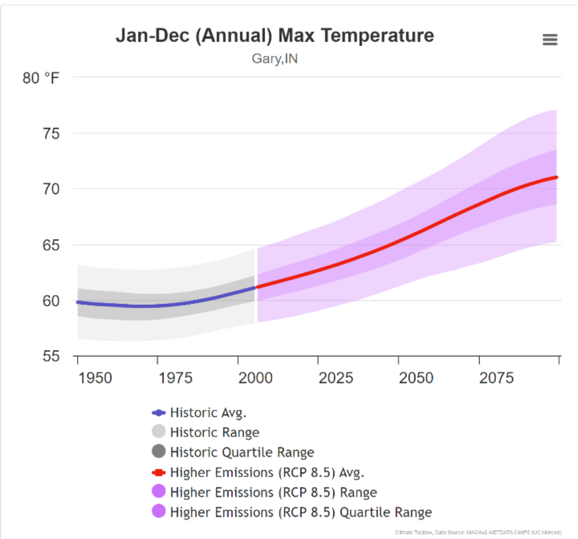
Figure A1-9. The number of days with precipitation events that exceed the 1900 to 2016 period's 99th percentile for Indiana (statewide average). The black line represents the trend line (0.2 days/decade) for the 1900 to 2016 period. Image from Widhalm et al. (2018).

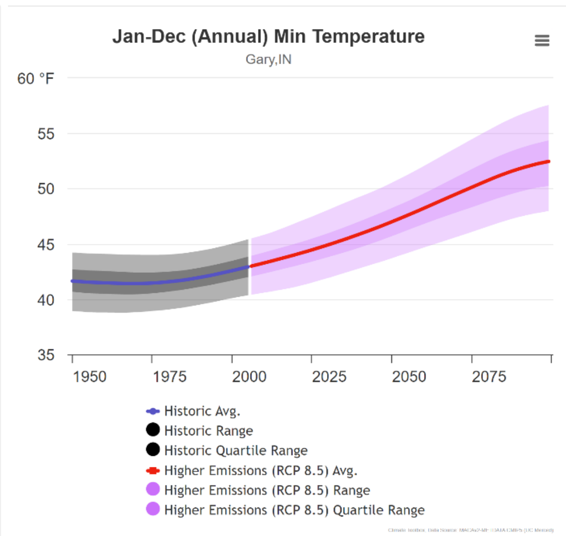
Past and Future Trends in City of Gary

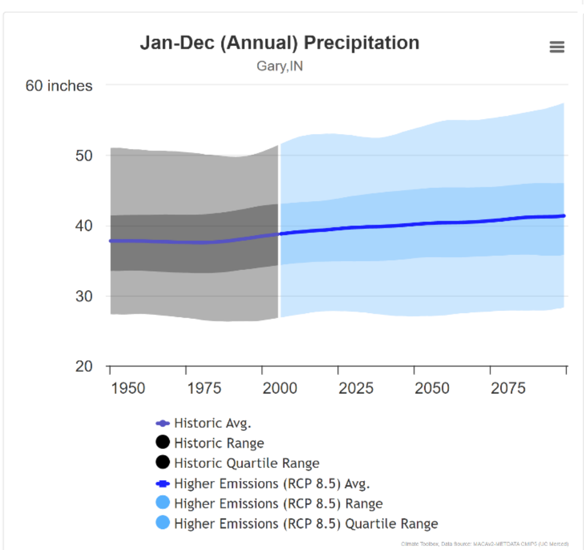
Temperature, Precipitation, and Potential Evapotranspiration

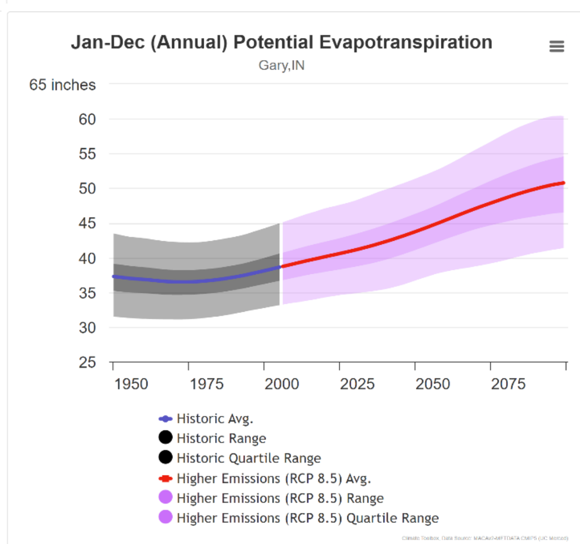
The Representative Concentration Pathway 8.5 (RCP 8.5) represents a high-emission scenario that assumes a future where no substantial efforts are made to mitigate greenhouse gas emissions. Often referred to as the "business-as-usual" or "baseline" scenario, it reflects a trajectory where fossil fuel consumption remains dominant and there is limited action to reduce emissions. In this scenario, the annual trend of climate variables in the City of Gary indicates a significant increase in both average maximum and minimum temperatures over the years. By the end of 2090, the average annual maximum temperature is expected to rise from around 62°F in 2023 to about 71°F. This suggests a noticeable escalation in peak temperatures experienced throughout the year. At the same time, the average minimum temperature is projected to increase from approximately 44°F in 2023 to about 52°F by 2090. This signifies warmer nights and milder winters, with the lowest temperatures encountered during the year becoming higher. These changes collectively point towards a long-term warming trend in the City of Gary. The average maximum temperature is predicted to rise by approximately 9°F, while the average minimum temperature is anticipated to increase by around 8°F over the course of almost seven decades. Such a temperature shift can have far-reaching implications for the environment, ecosystems, and human activities in the region.

On the other hand, while average annual precipitation is expected to increase from about 39.5 inches in 2023 to 41.1 inches in 2090, the rate of precipitation change is relatively modest compared to the temperature increase. This indicates a dryer climate as the temperature rises at a faster rate than the precipitation. The imbalance between temperature and precipitation trends raises concerns about potential impacts. This long-term warming trend is further supported by the potential evapotranspiration projection, which is estimated to increase from 40.6 inches in 2023 to 51 inches by the end of the same period. The significant rise in potential evapotranspiration, which represents the combined water loss through evaporation and plant transpiration, further emphasizes the increasing aridity and water demands resulting from the temperature changes. With a drier climate, the risk of drought conditions and water scarcity is heightened. Agriculture, ecosystems, and water resources may be negatively affected, and the likelihood of increased wildfire and poor air quality occurrences could also rise. This is supported by the potential evapotranspiration projection that goes from 40.6 inches to 51 inches in the same time frame.









Under the RCP 8.5 scenario (representing higher greenhouse gas emissions), the number of days with a maximum temperature exceeding 100°F is projected to increase significantly from around 2 days in the 2020s to approximately 33 days in the 2080s. However, under the RCP 4.5 scenario (with moderate emissions reductions), the number of such days increases to about 8 days. Conversely, the number of days with a minimum temperature below 32°F is projected to decrease from 118 days in the 2020s to 73 and 100 days in the RCP 8.5 and RCP 4.5 scenarios, respectively.

Heating Degree Days (HDD) measure the energy demand for heating, with a cumulative value of 1000 indicating colder weather and an increased need for heating. Cooling Degree Days (CDD) estimate the energy demand for cooling and are like HDD. In the context of the trends mentioned, the number of cooling degree days is projected to rise from approximately 1200 days in the 2020s to about 2500 days in the 2080s, while warming degree days decrease from 5700 to 4300.

The projected changes in temperature extremes and degree days have significant implications for various aspects of society and the environment. The substantial increase in the number of days with maximum temperatures exceeding 100°F under the RCP 8.5 scenario suggests more frequent and prolonged heatwaves, posing risks to human health, agriculture, and infrastructure. Additionally, the decrease in the number of days with minimum temperatures below 32°F indicates milder winters, potentially affecting ecosystems, cold-dependent industries, and water resources.

The contrasting outcomes between the RCP 8.5 and RCP 4.5 scenarios emphasize the importance of greenhouse gas emissions reductions. The moderate emissions reductions in the RCP 4.5 scenario result in a relatively lower increase in extreme heat days, providing some mitigation against heat-related impacts compared to the higher emissions pathway. However, even under the more moderate scenario, there is still a noticeable rise in extreme heat events.

The changes in heating and cooling degree days indicate shifts in energy demands for space heating and cooling. The increase in cooling degree days signifies a heightened need for air conditioning, potentially straining energy systems, increasing electricity consumption, and raising concerns about energy affordability and grid reliability. Conversely, the decrease in warming degree days suggests reduced energy requirements for heating but may have implications for industries and systems dependent on colder temperatures, such as winter tourism and snow-based recreation.

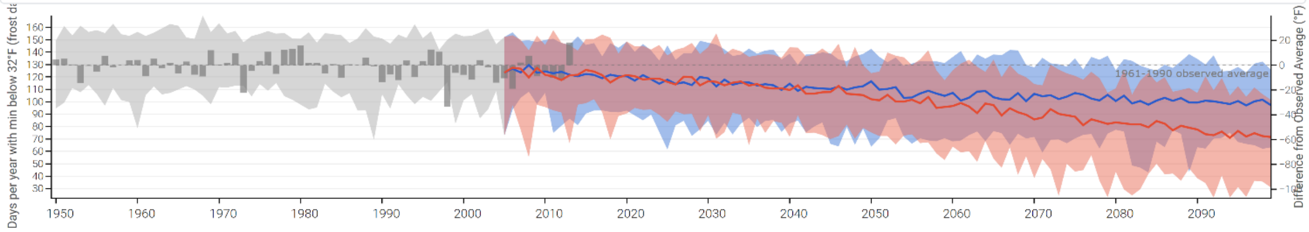
These projected implications highlight the importance of adaptation measures, sustainable energy planning, and policies aimed at reducing greenhouse gas emissions. By understanding and addressing these climate change impacts, communities can better prepare for temperature extremes, manage energy demands, protect vulnerable populations, and work towards a more resilient and sustainable future.

Gary, IN

Stations

Lake County - Days w/ minimum temp < 32°F

Days w/ minimum temp < 32°F | Graph | Map | Annual | Monthly | Downloads | About

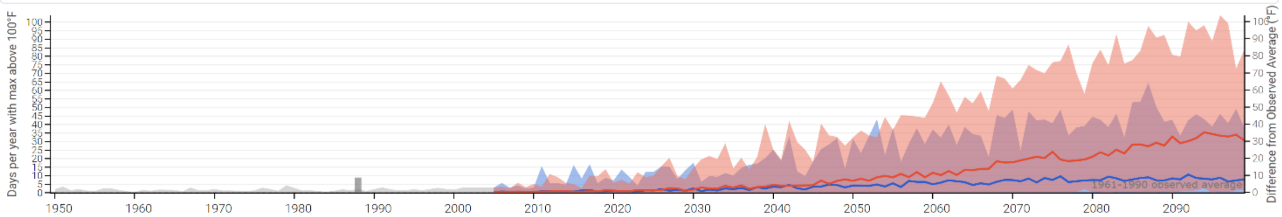


Gary, IN

Stations

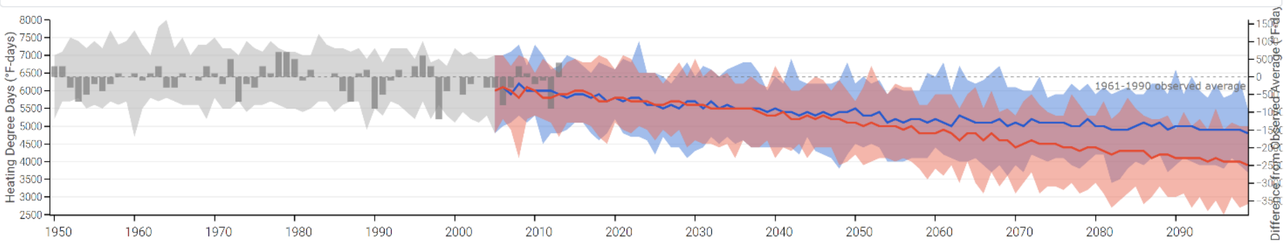
Lake County - Days w/ maximum temp > 100°F

Days w/ maximum temp > 100°F | Graph | Map | Annual | Monthly | Downloads | About



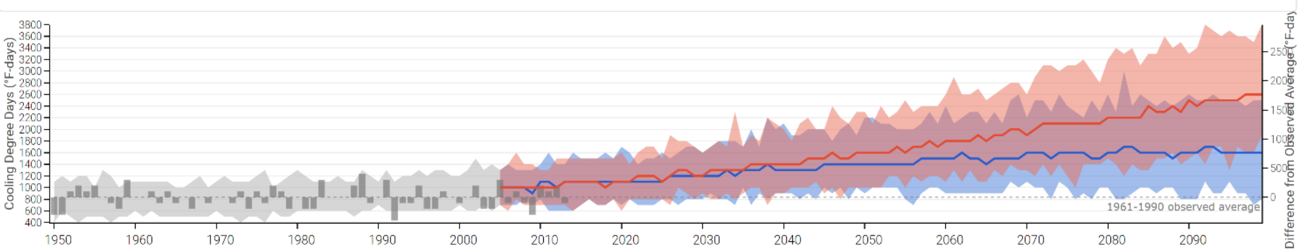
Lake County - Heating Degree Days

Heating Degree Days | Graph | Map | Annual | Monthly | Downloads | About



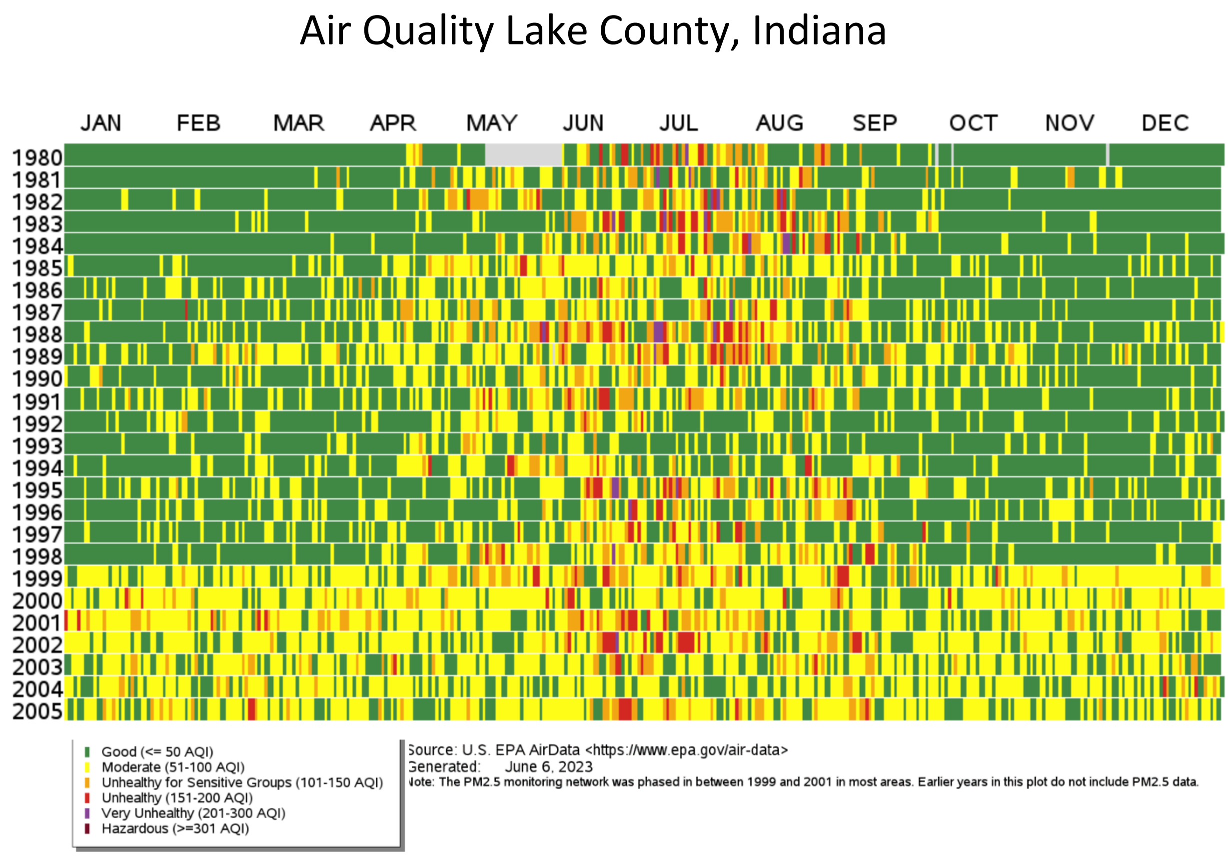
Lake County - Cooling Degree Days

Cooling Degree Days | Graph | Map | Annual | Monthly | Downloads | About



Observations | Modeled History | Lower Emissions | Higher Emissions

Air Quality in Lake County

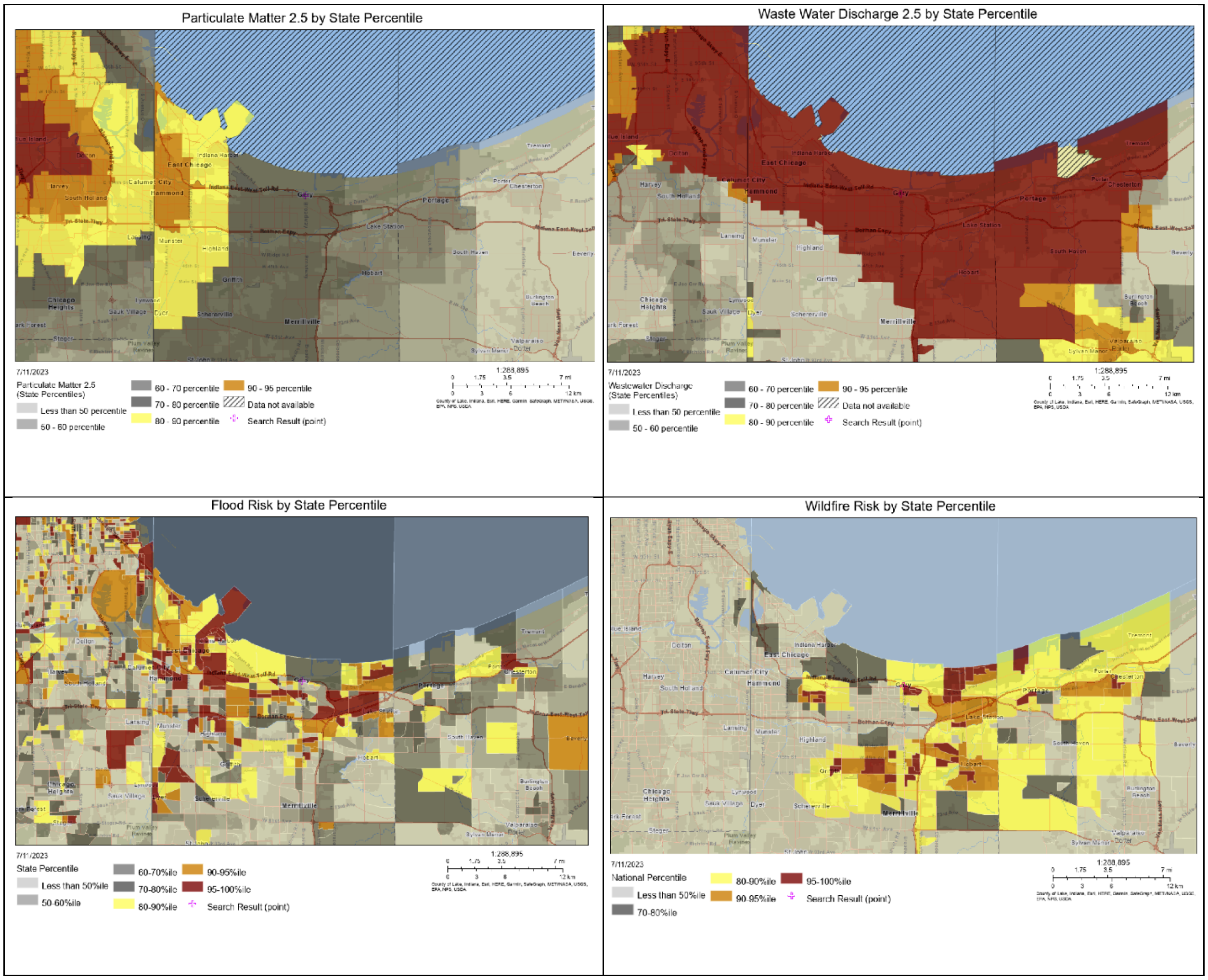


The Midwest region is identified as having the highest level of industrial pollution, with Indiana ranking at the top in terms of toxic emissions per square mile, according to the U.S. Environmental Protection Agency's Toxic Release Inventory. The image above offers a comprehensive and vivid representation of the significant decline in air quality within Lake County, Gary, spanning the period from 1980 to 2005. The visualization emphasizes the critical importance of adopting measures to achieve cleaner and more sustainable air in the region. By analyzing this data, we are prompted to take immediate action to address the pressing issue of air pollution, ensuring a healthier and more environmentally conscious future for the community.

Wastewater Discharge, Flood Risk, and Wildfire Risk in the City of Gary

The City of Gary surpasses 5% of days where the air quality fails to meet the standards set for fine particulate matter (PM 2.5), as outlined in the Gary Climate Action Plan. According to the EPA's Environmental Justice Screening and Mapping Tool that uses data since 2010, Gary falls within 60% - 80% percentile of PM 2.5 pollutant in the state of Indiana, that means, 60% to 80% of other cities in Indiana have less PM 2.5 pollutant than the City of Gary.

These findings have crucial implications for public health and the environment. The high level of industrial pollution in the Midwest, especially in Indiana, raises concerns about the potential adverse effects on air quality, waterways, and surrounding ecosystems. The significant percentage of days exceeding air quality standards for PM 2.5 in Gary suggests a heightened risk of respiratory issues and other health complications for the local population. It highlights the urgency to address and reduce pollution sources, improve industrial practices, and enhance air quality management measures.



According to the EPA tool, Gary has a relatively high level of Wastewater Discharge compared to other cities in Indiana (90% - 100% percentile range). This indicates that the majority of cities in Indiana have lower levels of wastewater discharge than Gary. This difference in wastewater discharge levels could have environmental and public health implications.

In terms of flood and wildfire risks, a significant portion of Gary (70% - 80% percentile range) is vulnerable to these natural disasters. Only a few locations remain unaffected, while the majority of areas face a considerable degree of risk. This heightened risk could lead to property damage, displacement of residents, and potential threats to life and safety.

In summary, the EPA tool reveals that Gary has a higher level of wastewater discharge compared to most cities in Indiana. Additionally, a significant portion of the city is vulnerable to flooding and wildfires. It is important to take proactive measures such as improving wastewater treatment systems, implementing land use planning, and establishing emergency preparedness measures to ensure the safety and well-being of the community in Gary.

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