As of November 5, 2026 · based on public sources checked up to this date

METHODOLOGY

Executive Summary

An analysis of thirty years of climate data for New York City (1995–2024) reveals a significant and accelerating warming trend. The annual mean temperature has increased by a total of 1.64°C over the study period, corresponding to a linear rate of +0.494°C per decade. This warming is not uniform across the calendar year; winter seasons have experienced the most rapid temperature rise at +0.554°C per decade, outpacing all other seasons. Concurrently, the frequency of extreme heat events has escalated, with days reaching maximum temperatures of 33°C or higher increasing by an average of 1.3 days per decade. Precipitation patterns have also shifted toward wetter conditions, with annual totals rising by +117.9 mm per decade.

+1.64°C
Total Warming
1995–2024

+0.554°C
Winter Warming Rate
per decade

+1.3
Hot Days Trend
days per decade

Accelerating Seasonal Warming

While the overall annual mean warming stands at +0.494°C per decade, the seasonal breakdown highlights distinct vulnerabilities. Winter is the fastest-warming season, exhibiting a rate of +0.554°C per decade, followed closely by Fall (+0.527°C/decade), Summer (+0.454°C/decade), and Spring (+0.443°C/decade). This disproportionate winter warming suggests that cold-season infrastructure and heating demands are facing structural shifts rather than simple cyclical variations. The acceleration in recent decades is stark: the decade average for annual mean temperatures rose from 11.60°C in the 1990s to 12.84°C in the 2020s, marking a clear upward trajectory in baseline thermal loads.

Escalation of Extreme Heat

Beyond the rising mean, the intensity of heat events poses direct risks to public health and urban energy grids. The data indicates a positive trend of +1.3 days per decade for hot days defined as having a maximum temperature of 33°C or above. Furthermore, warm nights—defined as nights where the minimum temperature reaches or exceeds 22°C—have become significantly more frequent, jumping from a decade average of 53 nights in the 1990s to 178 nights in the 2010s. These metrics underscore a shift toward sustained heat stress, where both daytime peaks and nighttime recovery thresholds are being breached more often.

Shift Toward Wetter Conditions

Precipitation trends reinforce the narrative of a changing climate regime. The mean annual precipitation for the full 30-year period was 1,165.6 mm, but with high year-to-year variability (standard deviation of 219.7 mm). Despite this volatility, a linear regression reveals an increasing trend of +117.9 mm per decade. Heavy rain events, defined as days exceeding 50mm of precipitation, totaled 41 days over the three decades, showing a slight upward trend of +0.4 days per decade. This combination of higher total rainfall and increased heavy precipitation events necessitates robust stormwater management planning to mitigate flooding risks.

> **METHODOLOGICAL NOTE**
> This executive summary provides a high-level overview of the key findings. Detailed statistical derivations, seasonal breakdowns, and specific limitations regarding data sources are presented in subsequent chapters of this report.

INTRODUCTION AND METHODOLOGY

Data & Methodology

This chapter defines the data sources, methodological framework, and inherent limitations that underpin the climate analysis presented in this report. The study relies on a comprehensive dataset spanning thirty years—from January 1, 1995, to December 31, 2024—to establish long-term climatic baselines for New York City.

Data Source: ERA5 Reanalysis

The primary data source for this analysis is the ERA5 atmospheric reanalysis, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) as part of the Copernicus Climate Change Service[9]. ERA5 is the fifth generation of ECMWF's reanalysis product, providing hourly estimates of numerous atmospheric, land, and oceanic climate variables on a global scale since January 1940[9].

Unlike traditional station observations, which rely on localized ground-based instruments subject to relocation or maintenance gaps, reanalysis data combines model forecasts with historical observational data to create a physically consistent, gap-free record[10]. This methodology ensures that the dataset covers exactly 10,958 daily rows from 1995 through 2024 with no missing values, providing a robust foundation for linear trend analysis and decade-by-decade comparisons.

DATASET SPECIFICATIONS

- **Data Provider:** Open-Meteo Historical Weather API
- **Source Product:** ERA5 Atmospheric Reanalysis (ECMWF)
- **Period of Record:** January 1, 1995 – December 31, 2024
- **Total Daily Rows:** 10,958 (Zero missing values)
- **Grid Resolution:** ~31 km (Reduced Gaussian grid N320)

Reanalysis vs. Local Station Observations

A critical distinction in climate science is the difference between point-measurements (local weather stations) and gridded reanalysis products. While local stations provide high-resolution, hyper-local readings at specific coordinates, they are inherently discontinuous. Station records often suffer from breaks caused by equipment upgrades, changes in measurement protocols, or physical relocation of the site over decades[10].

ERA5 circumvents these discontinuities by assimilating vast amounts of historical satellite, radar, and gauge data into a unified numerical weather prediction model. The result is a spatially continuous grid where every location has a modeled value for any given day. For this report, the ~31 km native horizontal grid resolution was utilized to generate daily mean temperatures, precipitation totals, and snowfall metrics for the New York City region. Because the data is derived from a global model rather than direct local instrumentation, it represents the climatological state of a 31 km × 31 km area centered on the city, rather than the exact microclimate of a single street corner.

Limitations: Urban Heat Island Effects

The most significant limitation of using a ~31 km resolution reanalysis grid for an urban environment like New York City is the inability to fully resolve the Urban Heat Island (UHI) effect. The UHI phenomenon describes how dense urban infrastructure—concrete, asphalt, and buildings—absorbs and retains solar heat, making cities significantly warmer than their surrounding rural areas.

Because the ERA5 grid cell averages temperature across a 31 km area encompassing both dense Manhattan skyscrapers and the cooler waters of the Hudson River or the green spaces of Central Park, the resulting data smooths out extreme localized peaks. Consequently, the annual mean warming trend of +0.494°C per decade reported in this document likely underestimates the actual temperature increase experienced within the densest urban cores. Conversely, the model may slightly overestimate winter minimum temperatures in highly insulated urban pockets compared to exposed suburban zones. However, because this smoothing applies uniformly across the entire 30-year period, the relative trends and decade-over-decade shifts remain scientifically valid indicators of broad regional climate change.

Statistical Methodology

All trend analyses in this report utilize simple linear regression to determine the direction and magnitude of climatic shifts over the 30-year window. Key statistical outputs include the slope of the regression line (expressed as change per decade) and the coefficient of determination (R^2).

The R^2 value indicates how well the linear model approximates the real data points, ranging from 0 (no explanatory power) to 1 (perfect fit). In the context of this report:

An R^2 above 0.30 suggests a strong linear relationship where the trend explains a substantial portion of the variance.

An R^2 between 0.10 and 0.30 indicates a moderate trend, where natural year-to-year variability plays a larger role than the directional shift.

An R^2 near 0.00 implies that a straight-line model is not useful for the data, and fluctuations are likely cyclical or random rather than structurally directional.

For example, while the annual precipitation trend shows an increasing slope of +117.9 mm per decade, its low R^2 of 0.22 confirms that wetter or drier years are driven heavily by natural oscillation rather than a strict linear trajectory. Similarly, the snowfall trend yields an R^2 of 0.00, demonstrating that a simple decline narrative cannot be statistically supported by the data.

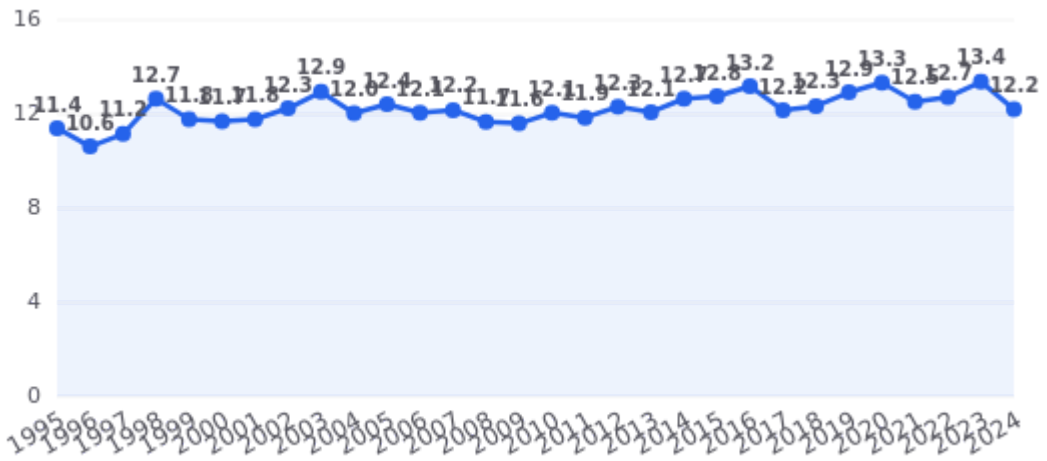
> **METHODOLOGICAL NOTE**
>
> This section defines the data sources and analytical boundaries. Specific findings regarding temperature anomalies, precipitation extremes, and seasonal breakdowns are detailed in subsequent chapters of this report.

TEMPERATURE ANALYSIS

Annual Mean Warming Trends

The analysis of annual mean temperatures for the study period (1995–2024) reveals a consistent and statistically significant upward trajectory. Based on ERA5 reanalysis data, the average annual temperature in New York City has increased by +0.494°C per decade. This warming trend is

characterized by an R^2 value of 0.3327, indicating that approximately one-third of the variance in annual mean temperatures can be explained by this linear temporal progression. Over the full 30-year span, the cumulative increase in the annual mean temperature reached 1.64°C, reflecting a substantial shift in the region's baseline climatic conditions.



NYC Annual Mean Temperature (1995–2024)

While the regional context notes that annual average temperatures across New York State have risen more than 2.5°F since the beginning of the 20th century[8], the specific focus on the last three decades highlights an acceleration in recent years. The United States Climate Normals, updated decadal averages used as standard baselines for climate comparison, transitioned from the 1981–2010 period to the 1991–2020 period in May 2021[6]. These normals serve as a critical ruler for comparing current weather against historical averages, and the observed deviations within these updated norms underscore the rapidity of local warming.

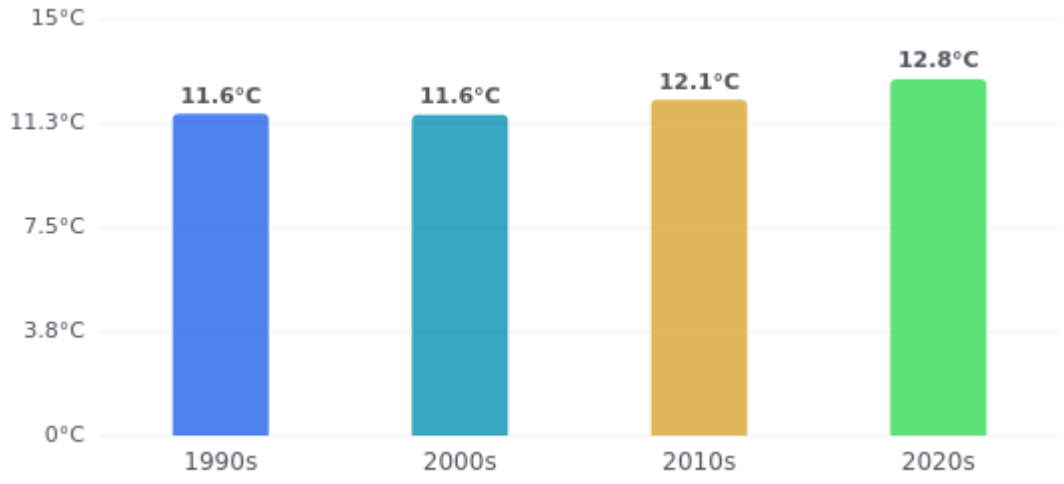
KEY INSIGHT

Accelerated Warming in the 2020s

Even as a partial decade, the 2020s have already established a new high-water mark for annual mean temperatures, surpassing all previous decades recorded in the dataset.

Decade-by-Decade Temperature Comparison

To contextualize the linear trend, it is instructive to examine the average annual mean temperatures calculated for each decade within the observation window. The data demonstrates that the warming is not merely a steady slope but exhibits distinct step-changes, particularly between the 2010s and the current decade.



The table below details the precise average temperatures for each decade, providing a clear snapshot of the shifting climate baseline.

DECADE	AVERAGE ANNUAL MEAN TEMPERATURE
1990s	11.60°C
2000s	11.56°C
2010s	12.09°C
2020s (partial)	12.84°C

During the 1990s and 2000s, the annual mean temperature remained relatively stable, hovering around 11.6°C. In fact, the 2000s recorded a marginally lower average (11.56°C) than the preceding decade (11.60°C), suggesting a period of climatic equilibrium or natural variability masking the underlying long-term trend. However, a structural break occurred entering the 2010s, where the average jumped to 12.09°C—an increase of roughly half a degree over the prior two decades.

The most striking development is observed in the 2020s. Despite representing only a partial decade (data ending in late 2024), the average annual mean temperature has surged to 12.84°C. This figure represents a dramatic 0.75°C leap from the 2010s average alone. If this trajectory holds for the remainder of the decade, the 2020s will likely stand as the warmest period in the entire 30-year record, reinforcing the +0.494°C/decade linear trend while highlighting an acceleration in the rate of warming during the most recent years.

The implications of this rising baseline are profound for urban infrastructure and public health planning. As noted in the Fourth New York City Panel on Climate Change (NPCC4) reports and supported by broader state-level summaries, historically unprecedented warming is projected to continue under intermediate and higher emissions pathways[8]. The shift from a stable ~11.6°C environment to a sustained >12.8°C environment fundamentally alters the energy demands for building cooling, increases the risk of heat-related illnesses, and exacerbates the Urban Heat Island (UHI) effect in densely populated areas like New York City.

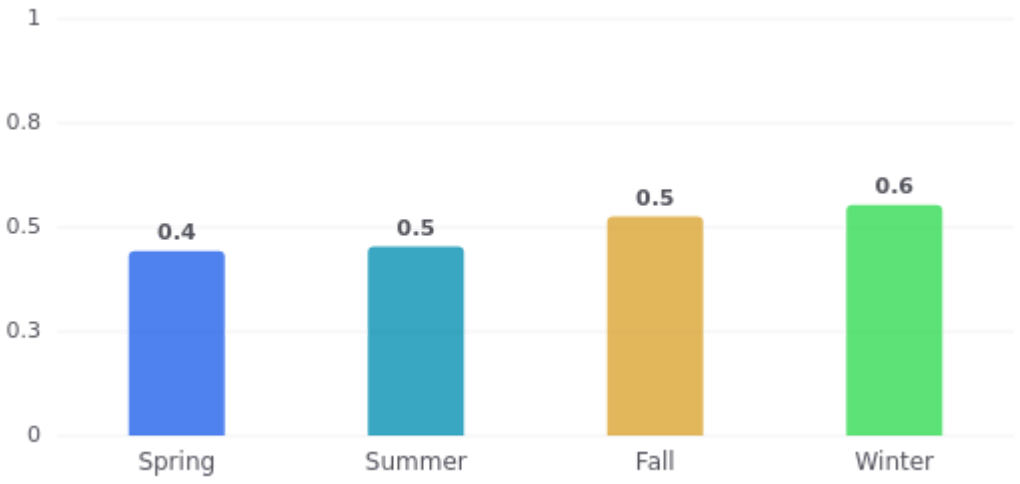
> **DATA CONTEXT**
>
> The data utilized in this section relies on the ERA5 reanalysis product from the European Centre for Medium-Range Weather Forecasts (ECMWF). Unlike traditional station-based observations, which can suffer from breaks due to instrument changes or station relocations, ERA5 combines model forecasts with observational data to create a spatially consistent and homogeneous historical record[1]. This ensures that the observed trends reflect genuine atmospheric changes rather than artificial discontinuities in the measurement process.

Note: Seasonal breakdowns of these warming rates and detailed analyses of extreme heat events (such as hot days ≥33°C) are covered in separate sections of this report.

TEMPERATURE ANALYSIS

Seasonal Warming Rates

While the annual mean temperature trend provides a baseline for understanding regional climate change, examining seasonal breakdowns reveals significant asymmetries in how warming is distributed throughout the year. The ERA5 reanalysis data from 1995 to 2024 demonstrates that winter and fall seasons are experiencing accelerated warming compared to summer and spring. This non-uniform distribution of heat has profound implications for urban infrastructure, public health, and energy demand cycles.



Warming Rate by Season (°C/decade)

KEY FINDING

Winter is the fastest-warming season

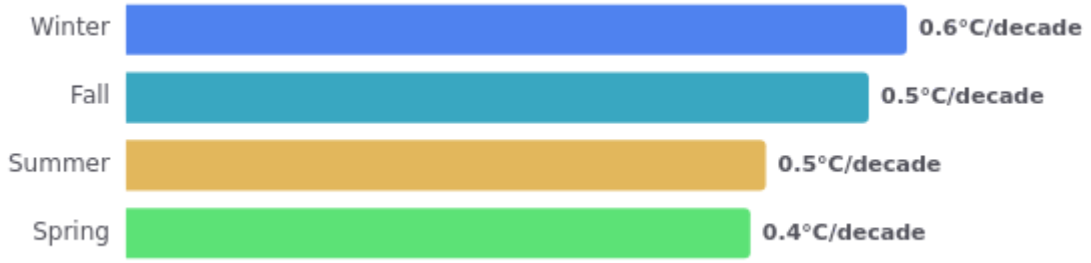
Winter temperatures increased at a rate of +0.554°C per decade, outpacing the annual average of +0.494°C/decade. Fall followed closely at +0.527°C/decade.

The Asymmetry of Seasonal Change

The seasonal analysis of New York City's climate from 1995 to 2024 highlights a distinct pattern of "asymmetric warming." Rather than a uniform rise across all four seasons, the data indicates that the cold half of the year (fall and winter) is warming significantly faster than the warm half (summer and spring). This

phenomenon is consistent with broader regional climate change trends captured by the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 reanalysis data[1].

The most pronounced warming occurs during winter, which recorded a trend of +0.554°C per decade. This rate exceeds the annual mean warming trend of +0.494°C/decade by a notable margin, indicating that winters are not only becoming warmer but are doing so at an accelerating pace relative to the yearly average. Fall follows as the second-fastest warming season at +0.527°C/decade, reinforcing the dominance of cold-season warming. In contrast, summer and spring exhibit slower rates of increase, registering at +0.454°C/decade and +0.443°C/decade, respectively.



Implications for Heating Demand and Freezing Duration

The disproportionate warming during winter and fall carries critical implications for urban planning and resource management, particularly regarding heating demands and the duration of freezing conditions. A warming rate of +0.554°C per decade in winter suggests a steady reduction in the intensity and frequency of extreme cold events. This shift directly translates to decreased heating degree days (HDD), which are metrics used to estimate energy consumption required for building heating.

For city planners and utility providers, this trend implies a structural decline in peak heating demand over time. Buildings designed or retrofitted based on historical cold extremes may find themselves over-capacity for heating needs within a few decades. Conversely, the slower warming rates in summer (+0.454°C/decade) and spring (+0.443°C/decade) suggest that cooling demands will continue to rise, albeit at a slightly more moderate pace compared to the rapid mitigation of heating loads. This divergence necessitates a recalibration of energy infrastructure investments, shifting focus toward maximizing cooling efficiency while maintaining flexible heating systems capable of handling residual cold snaps.

Furthermore, the accelerated winter warming contributes to a shorter freezing duration. Thawing events occur more frequently, and periods of sustained sub-zero temperatures become less predictable. This volatility poses challenges for municipal snow removal operations, road maintenance protocols, and public safety measures traditionally calibrated for long, stable winter freezes. Infrastructure materials subject to freeze-thaw cycles may experience altered degradation patterns, requiring updated standards for durability in construction projects.

Regional Context and Projections

These observed seasonal trends align with broader findings from state-level assessments. The New York State Climate Impacts Assessment notes that rising temperatures are already evident and projected to worsen, with associated decreases in cold wave intensity[8]. Similarly, the Fourth New York City Panel on Climate Change (NPCC4) anticipates establishing new projections-of-record for temperature based on continued analysis, further validating the significance of these seasonal shifts[2].

The data underscores the necessity of adopting adaptive strategies that account for seasonal asymmetry. While the overall annual warming trend provides a useful aggregate metric, relying solely on it risks underestimating the specific vulnerabilities associated with rapid winter and fall changes. Urban resilience planning must therefore incorporate granular, season-specific data to ensure that infrastructure, public health interventions, and energy policies remain effective in a changing climate regime.

TEMPERATURE ANALYSIS

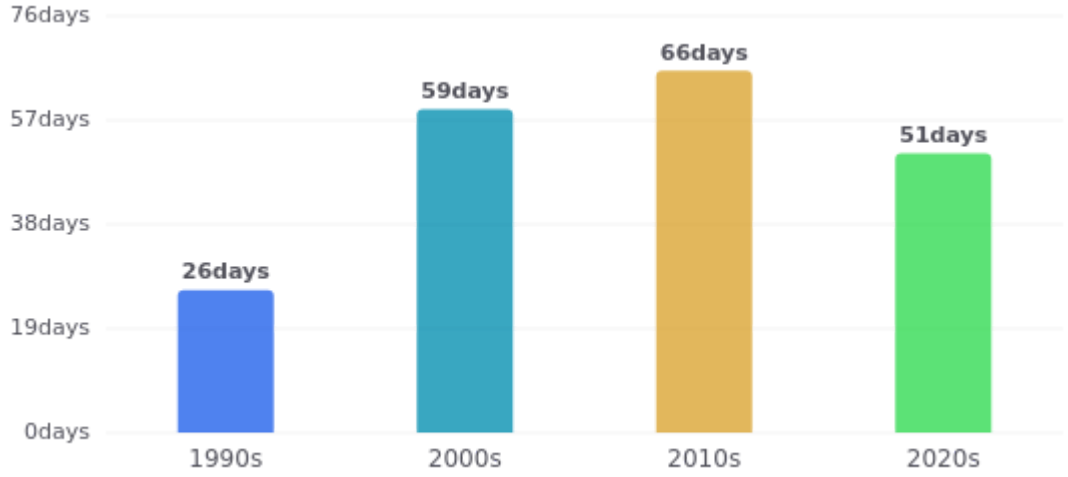
Extreme Heat Indicators

While mean temperature trends provide a broad overview of the climate regime, they mask the intensity and frequency of extreme heat events that pose the most significant risks to public health and urban infrastructure. The analysis of heat stress indicators—specifically hot days (maximum temperature ≥33°C) and warm nights (minimum temperature

≥22°C)—reveals an accelerating shift in thermal extremes over the 1995–2023 period. These metrics capture the "floor" and "ceiling" of daily temperatures, highlighting how both daytime peak heat and nighttime recovery thresholds have fundamentally altered the city's thermal environment.

Escalation of Hot Days

The frequency of days reaching or exceeding 33°C has shown a marked increase, particularly between the 1990s and the 2010s. In the 1990s, the city experienced an average of only 26 such hot days per decade. This figure more than doubled in the 2000s to 59 days, and peaked in the 2010s at 66 days. This trajectory indicates a structural intensification of summer heat waves, where high temperatures are no longer isolated anomalies but recurring seasonal features. The linear trend for these events is estimated at +1.3 days per decade. However, the 2020s have recorded 51 hot days so far; while this is lower than the 2010s peak, it must be noted that the 2020s dataset is incomplete as it covers only the first half of the decade (1995–2024).



The Nighttime Warming Crisis

Perhaps more critical than daytime highs is the dramatic reduction in nighttime cooling. Warm nights, defined as those with minimum temperatures reaching or exceeding 22°C, have nearly quadrupled over the study period. In the 1990s, there were 53 warm nights per decade. This number rose to 105 in the 2000s and surged to 178 in the 2010s. By the 2020s, the count stood at 92 nights, reflecting a continued prevalence of tropical nights that prevent the urban environment from recovering from daytime heat accumulation.

This phenomenon is heavily influenced by the Urban Heat Island (UHI) effect, where dense infrastructure absorbs solar radiation during the day and re-radiates it slowly at night. The persistence of high minimum temperatures exacerbates heat-related mortality. According to the 2026 NYC Heat-Related Mortality Report, approximately 500 New Yorkers die prematurely because of hot weather in New York City. Of these, about 490 are "heat-exacerbated deaths," where heat worsens underlying cardiovascular or respiratory conditions. The report highlights that heat-exacerbated deaths increased in the previous decade, driven mainly by hotter summers featuring more "non-extreme hot days" (temperatures between 82°F and 95°F)—precisely the range associated with elevated minimum temperatures[11].

The inequity of this exposure is stark. Black New Yorkers experience heat-stress death rates three times higher, and Latino New Yorkers two times higher, than their white counterparts. This disparity is linked to structural factors such as lack of access to home cooling and housing quality, which directly affect residents' ability to survive these increasingly frequent warm nights[11].

Higher Threshold Nights

Beyond the standard 22°C threshold, the data reveals a troubling rise in even warmer nights, indicating that the baseline for "nighttime warmth" itself is shifting upward. The frequency of nights with minimum temperatures of 24°C or higher has tripled from the 1990s to the 2010s. Similarly, nights reaching a minimum of 25°C—a level often associated with severe sleep disruption and acute heat exhaustion risk—have also seen consistent growth.

INDICATOR	1990S	2000S	2010S	2020S
Hot Days (≥33°C)	26	59	66	51
Warm Nights (≥22°C)	53	105	178	92
Min ≥24°C Nights	9	15	27	11
Min ≥25°C Nights	5	8	12	4

The data for minimum temperatures ≥24°C shows a clear acceleration: rising from just 9 nights in the 1990s to 27 nights in the 2010s before dropping to 11 in the partial 2020s. The ≥25°C metric follows a similar, albeit smaller-scale, pattern, increasing from 5 nights in the 1990s to 12 in the 2010s. These extreme

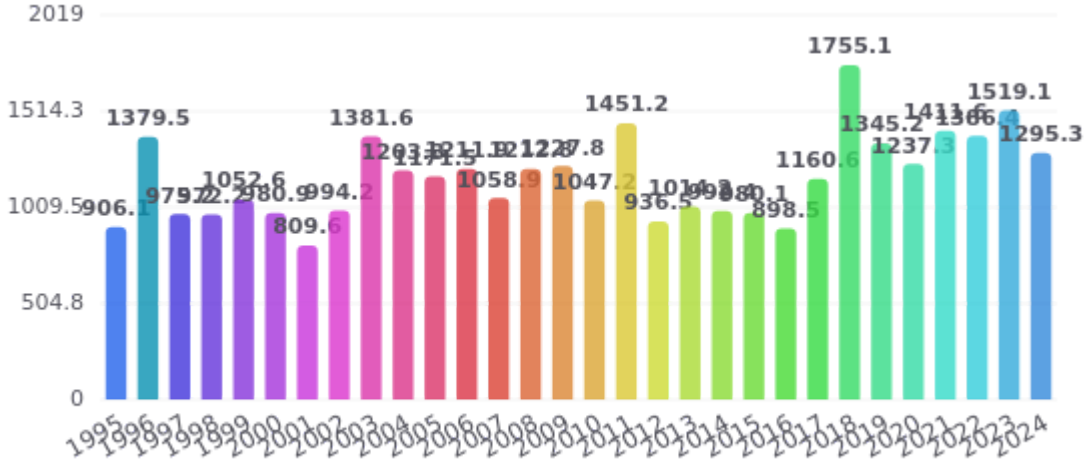
nighttime lows suggest that as global warming continues, the city will face not just more hot days, but an environment where the fundamental biological respite of cool nights becomes increasingly rare.

> **PUBLIC HEALTH ALERT**
>
> WHO notes that heat stress is a leading cause of weather-related deaths globally, with mortality among those over 65 increasing by approximately 85% between 2000–2004 and 2017–2021[12]. The rapid rise in warm nights in New York City aligns with this global vulnerability profile, underscoring the urgent need for equitable investments in structural cooling interventions.

PRECIPITATION AND SNOWFALL PATTERNS

Annual Precipitation Variability

While temperature metrics provide a clear signal of long-term warming, precipitation patterns in New York City exhibit significantly higher interannual variability. The total volume of rainfall and snowmelt falling on the city each year fluctuates widely, governed by complex interactions between atmospheric circulation, sea surface temperatures, and local storm tracks. Analyzing annual precipitation totals is essential for understanding water resource management, flood risk, and the hydrological impacts of climate change.



Annual Precipitation Totals (1995-2024)

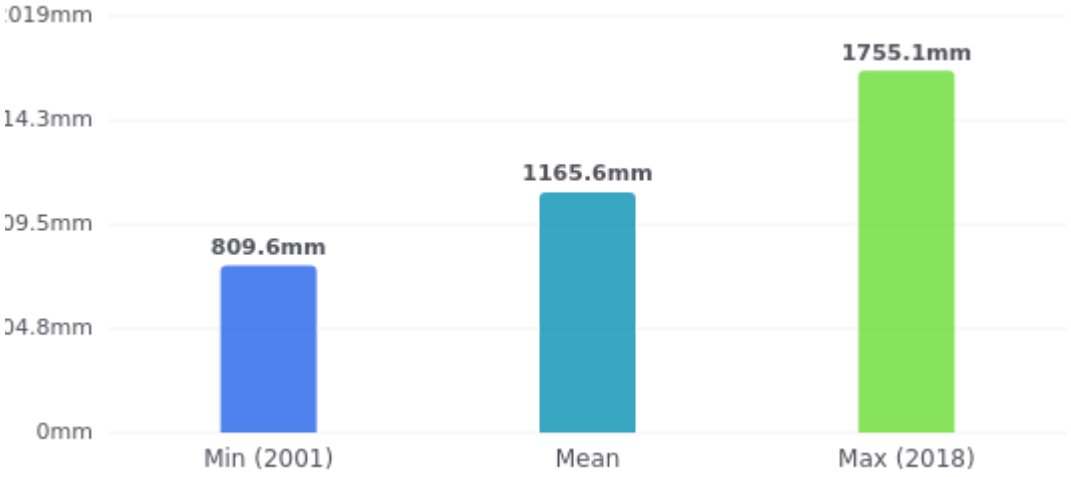
KEY STATISTICS

1,165.6 mm	± 219.7 mm	+117.9 mm	0.22
Mean Annual	Standard Deviation	Trend per Decade	R^2 Value

Central Tendency and Dispersion

Over the 30-year study period (1995–2024), the mean annual precipitation total was 1,165.6 mm. However, relying solely on the mean obscures the extreme volatility inherent in the dataset. The standard deviation stands at a substantial 219.7 mm, representing nearly 19% of the mean value. This high degree of dispersion indicates that "average" years are statistically rare; most years deviate significantly from the 1,165.6 mm baseline.

The range of annual totals further illustrates this instability. The driest year on record occurred in 2001, with a total of just 809.6 mm, which is 356 mm below the 30-year average. Conversely, the wettest year was 2018, recording 1,755.1 mm—an excess of 589.5 mm over the mean. The difference between the minimum and maximum years (945.5 mm) underscores the capacity of New York's climate to swing from severe dryness to extreme saturation within a single decade.



Long-Term Upward Trend

Despite the chaotic year-to-year fluctuations, a linear regression analysis reveals a distinct upward trend in annual precipitation volumes. The data indicates an increase of +117.9 mm per decade. In practical terms, this suggests that each successive decade receives roughly 12 cm more precipitation than the previous one. Over the full 30-year span, this accumulates to a total shift of approximately 354 mm, a significant hydrological change.

The coefficient of determination (R^2) for this trend is 0.22. While this confirms a positive correlation, it also highlights that the linear model explains only 22% of the variance in annual precipitation. This low explanatory power reinforces that natural variability—such as El Niño-Southern Oscillation (ENSO) cycles or North Atlantic Oscillation (NAO) phases—dominates the annual precipitation signal, masking the underlying climatic trend in any given single year.

Comparative Analysis: First vs. Last 15 Years

To contextualize the recent acceleration of this trend, the dataset can be divided into two halves: the first 15 years (1995–2009) and the last 15 years (2010–2024). This comparison isolates the most recent era of accelerated warming and provides a clearer picture of the structural shift in the city's hydrology.

INDICATOR	FIRST 15 YEARS (1995–2009)	LAST 15 YEARS (2010–2024)	DIFFERENCE
Mean Annual Precipitation	1,102.5 mm	1,228.7 mm	+126.2 mm
Trend Contribution	Consistent with the +117.9 mm/decade long-term slope		

The mean annual precipitation increased from 1,102.5 mm in the first half of the period to 1,228.7 mm in the second half—a net gain of 126.2 mm. This 11.4% increase in the average wetness of the city aligns closely with the projected trajectory derived from the full-period linear trend. It confirms that the latter half of the study period has been consistently wetter than the former, supporting the hypothesis of a intensifying hydrological cycle driven by regional climate change.

Implications for Urban Infrastructure

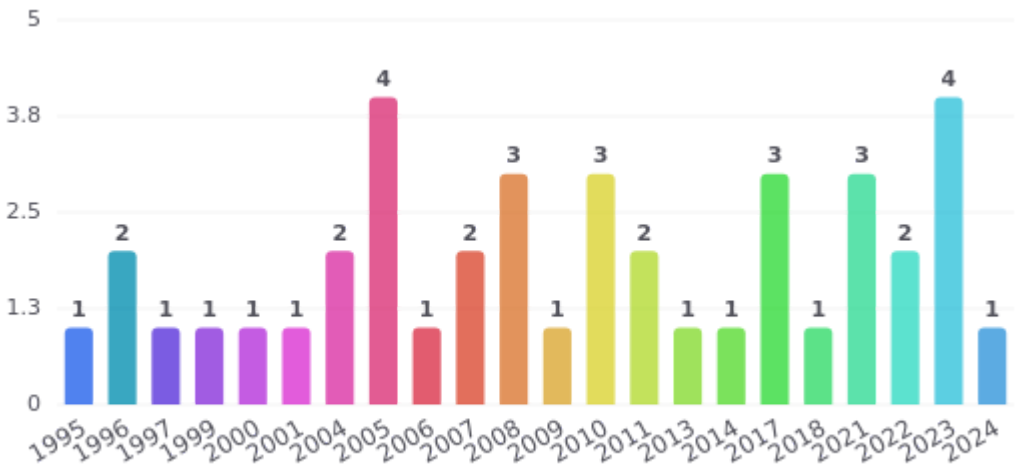
The combination of a rising mean and high standard deviation presents specific challenges for urban planning. A +117.9 mm per decade increase implies that stormwater drainage systems designed based on historical "100-year flood" probabilities may be operating outside their intended parameters. Furthermore, the high volatility means that infrastructure must be resilient to both extremes: the 800 mm droughts that stress water supply and treatment plants, and the 1,700+ mm deluges that overwhelm combined sewer systems.

As noted in broader assessments, such as the New York State Climate Impacts Assessment, these shifts in precipitation regimes are accompanied by rising temperatures and sea levels, compounding the risks for coastal and low-lying infrastructure[4]. The data does not merely show more rain; it shows a fundamentally wetter and more unpredictable baseline against which all future municipal planning must be calibrated.

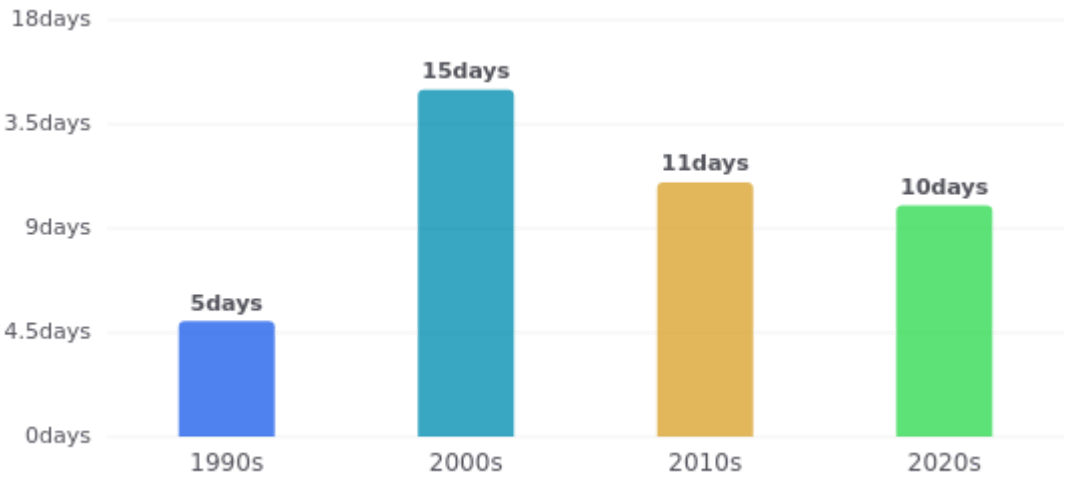
PRECIPITATION AND SNOWFALL PATTERNS

Heavy Rain Events

While the total volume of annual precipitation provides a measure of overall wetness, the frequency and intensity of individual extreme rainfall events represent a distinct and more destructive climate risk. Over the 30-year study period (1995–2024), the data identifies 41 days where precipitation exceeded 50 millimeters. These "heavy rain days" are not merely statistical outliers; they are critical drivers of urban infrastructure stress, as municipal drainage systems and stormwater management capacity are typically designed for specific return intervals that these events frequently exceed. The analysis of heavy rain days reveals a complex pattern characterized by a peak in the early 21st century followed by a plateau, rather than a simple linear escalation.



Heavy Rain Days (>50mm) by Year



The distribution of these 41 extreme events across decades highlights a significant concentration in the 2000s. During this ten-year window, New York City experienced 15 heavy rain days, representing nearly 37% of all such events recorded over the entire 30-year span. This surge suggests a period of heightened atmospheric instability or specific climatic oscillations that favored intense convective rainfall during those years. By contrast, the preceding decade (1990s) saw only 5 such days, indicating a relatively quieter baseline for extreme precipitation at the start of the study period.

Following the peak in the 2000s, the frequency moderated but remained elevated compared to the 1990s. The 2010s recorded 11 heavy rain days, while the partial data for the 2020s (covering 2020 through 2024) shows 10 days. When viewed on

a linear trend line, the long-term trajectory indicates an increase of +0.4 days per decade, though the coefficient of determination ($R^2=0.10$) is exceptionally low. This low R^2 value is analytically crucial: it signifies that the linear signal is weak and that heavy rain day counts are dominated by high interannual variability rather than a steady, predictable climb. In practical terms, this means that while the long-term risk profile may be shifting upward, any single year can deviate sharply from the trend without contradicting the broader dataset.

A comparative analysis of the first and second halves of the study period further illuminates the shift in precipitation behavior. Breaking the timeline into two 15-year segments reveals a tangible acceleration in the annual frequency of extreme rainfall.

PERIOD	HEAVY RAIN DAYS (>50MM)	AVG DAYS/YEAR
First 15 Years (1995–2009)	20	1.7
Last 15 Years (2010–2024)	21	2.1

In the first 15 years (1995–2009), residents and city planners averaged 1.7 heavy rain days per year. In the subsequent 15 years (2010–2024), this average rose to 2.1 days per year. Although the absolute difference of 0.4 days per year might appear minor, it effectively doubles the exposure risk over time. For municipal emergency services, a jump from roughly two major flood-triggering storms annually to two-and-a-half has profound implications for resource allocation, staffing requirements, and public safety protocols. Furthermore, because heavy rain events often occur outside of standard business hours or during seasonal transitions, even small increases in frequency can lead to disproportionate economic damage if they strike critical infrastructure nodes.

It is important to contextualize these figures within the broader findings of this report. While temperature metrics show robust linear trends—such as the +0.494°C warming per decade with a much stronger R^2 of 0.3327—heavy precipitation behaves differently. The low explanatory power of the linear trend for heavy rain days ($R^2=0.10$) implies that natural climate variability plays a massive role alongside anthropogenic warming. Warmer atmospheres hold more moisture, which generally supports the expectation of more frequent or intense downpours; however, the timing and occurrence of these events remain highly stochastic. Consequently, planning for heavy rain cannot rely solely on

extrapolating a straight line forward. Instead, infrastructure resilience must be designed to handle the upper bounds of historical extremes, acknowledging that the next decade could easily see a cluster of events similar to the 2000s peak. The concentration of heavy rain days in the 2000s also invites scrutiny of specific meteorological drivers. Decades with high counts often correlate with strong El Niño-Southern Oscillation (ENSO) phases or specific Atlantic hurricane tracks that deliver tropical moisture to the Northeast. The 2010s, for instance, included notable events associated with severe coastal storms, contributing to its count of 11 days despite being lower than the 2000s peak. As the climate continues to warm, the thermodynamic potential for these storms to produce heavy rainfall intensifies, even if the dynamical triggers (the weather patterns themselves) fluctuate naturally. Therefore, the observed rise from 1.7 to 2.1 days per year serves as an empirical warning: the baseline volatility of NYC's precipitation regime is increasing, demanding adaptive strategies that prioritize rapid response capabilities and flexible infrastructure over static design standards.

PRECIPITATION AND SNOWFALL PATTERNS:

Snowfall Volatility:

Contrary to the widespread narrative of a steady decline in winter snowfall, New York City's 30-year record reveals high volatility with no statistically significant long-term trend. The latter half of the study period actually experienced higher average snowfall than the first.

A common assumption about climate change is that it inevitably leads to less snow. However, the observational data from New York City between 1995 and 2024 tells a more complex story. While the global and regional climate is warming, the specific metric of annual winter snowfall has not followed a linear downward path. Instead, it has exhibited extreme year-to-year volatility, driven by powerful interannual weather patterns rather than a simple directional shift.

The Illusion of Decline:

When analyzing the full 30-year dataset, the linear regression slope for winter snowfall is slightly negative at -0.7 cm per decade. At first glance, this might suggest a slow erosion of winter snow. However, the statistical reliability of this

trend is effectively zero. The coefficient of determination (R^2) for this linear model is 0.00, meaning the straight line explains none of the variance in the data. In statistical terms, a flat line is just as good a predictor as a declining one. This indicates that the concept of a "steady decline" is an artifact of forcing a linear model onto highly chaotic data.

The reality of NYC's winter precipitation is defined by massive swings. Over the three decades, total annual winter snowfall ranged from a minimum of 9.7 cm in 1998 to a maximum of 101.4 cm in 2010. The mean annual snowfall was 46.5 cm, but the standard deviation was a massive 24.2 cm. To put this in perspective, the standard deviation represents more than half of the average itself. This means that in any given year, the actual snowfall could easily deviate from the average by over 20 cm in either direction. Such high variability is characteristic of systems dominated by episodic events—such as intense Nor'easters or coastal lows—rather than gradual climatic shifts.

KEY INSIGHT:

Volatility Over Trend:

With an R^2 value of 0.00, the linear trend for snowfall is statistically meaningless. The data is better described by its extremes (9.7 cm to 101.4 cm) and high standard deviation (24.2 cm) than by a slow decline.

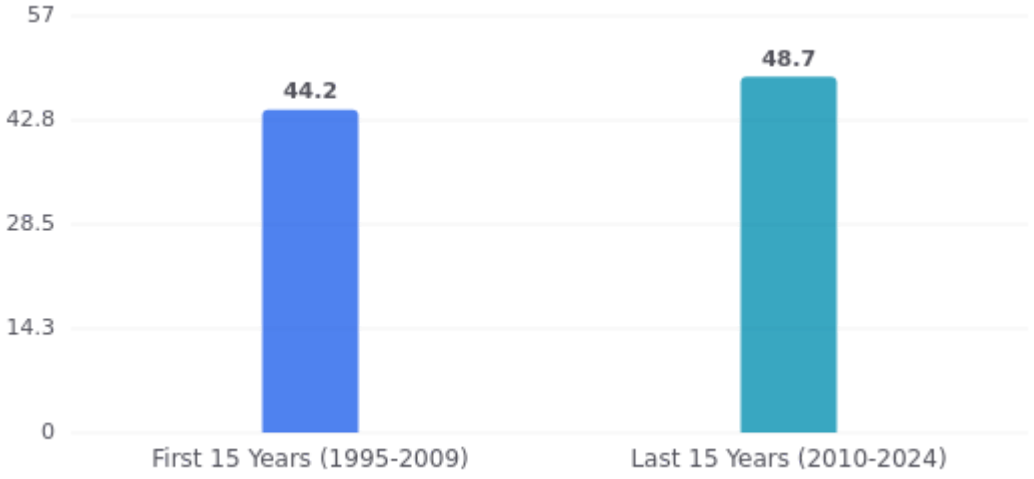
First Half vs. Last Half: A Reversal:

Perhaps the most compelling evidence against the "declining snow" narrative is found when splitting the 30-year period into two distinct halves. If a steady decline were occurring due to warming temperatures, the second half of the period should show significantly lower averages than the first. The data shows the exact opposite.

Comparing the first 15 years (1995–2009) to the last 15 years (2010–2024), the average winter snowfall actually increased. The first half of the period saw a mean of 44.2 cm, while the second half recorded a mean of 48.7 cm. This represents a difference of +4.4 cm, indicating that, on balance, the recent era has been slightly snowier than the earlier era within this specific dataset.

PERIOD	YEARS COVERED	AVG. WINTER SNOWFALL
First 15 Years	1995 – 2009	44.2 cm
Last 15 Years	2010 – 2024	48.7 cm
Difference	-	**+4.4 cm**

This reversal highlights the danger of extrapolating short-term trends over long periods. The peak snowfall year of the entire dataset occurred in 2010 (101.4 cm), right at the beginning of the second half. Conversely, the lowest snowfall year occurred in 1998 (9.7 cm), during the first half. These outliers drive the difference between the two periods, demonstrating that individual storm tracks and atmospheric conditions play a far larger role in annual totals than the background temperature trend.



Drivers of Variability:

The lack of a clear trend does not mean that climate change has no effect on winter weather. Rather, it suggests that the mechanisms driving snowfall are different from those driving temperature. Warmer air can hold more moisture, which can lead to more intense precipitation events when temperatures are cold enough. In New York City, this often manifests as heavy rain or a mix of rain and snow, rather than consistent light snowfall.

Furthermore, the North Atlantic Oscillation (NAO) and other large-scale climate patterns influence whether storms track inland toward New York or stay out at sea. During positive NAO phases, the jet stream tends to be stronger and further north, often keeping nor'easters away from the city. During negative phases, storms are more likely to stall along the East Coast, dumping significant snow. The 30-year window of 1995–2024 captures several transitions between these phases,

resulting in the observed volatility. For instance, the extremely snowy winter of 2009-2010 coincided with a strong negative NAO phase, while some of the snowiest winters in the early 2000s occurred under different atmospheric configurations.

It is also important to distinguish between "snowfall" and "winter precipitation." As noted in the previous section on precipitation variability, total annual precipitation has shown an increasing trend of +117.9 mm per decade. This wetter regime may be shifting the form of winter precipitation. Some winters may see less total snow accumulation because a higher percentage of winter precipitation falls as rain or sleet due to warmer surface temperatures. However, this does not necessarily mean fewer winter storms; it may mean that the storms are producing more liquid-equivalent precipitation, even if the snow depth is reduced.

Implications for Urban Planning:

For city planners and infrastructure managers, the takeaway from this volatility is critical. Designing for "average" snowfall is insufficient when the standard deviation is so high. A system built to handle 44 cm of snow (the 15-year average) would be severely overwhelmed in a year like 2010 (101.4 cm). Therefore, resilience planning must focus on extreme event capacity rather than long-term averages.

The data supports maintaining robust snow removal infrastructure capable of handling historic highs, even if the "typical" year appears moderate. Additionally, the possibility of mixed-phase precipitation (rain/snow) means that road treatment strategies must account for ice formation from freezing rain, not just snow accumulation. The high volatility confirms that winter weather in New York City remains inherently unpredictable on a year-to-year basis, requiring flexible and adaptive management strategies rather than static assumptions based on past averages.

SYNTHESIS AND IMPLICATIONS

First 15 vs Last 15 Years Comparison

To understand the trajectory of New York City's climate over the past three decades, a direct comparison between the first half of the study period (1995–2009) and the second half (2010–2024) provides the clearest view of structural shifts. While individual years fluctuate wildly due to natural variability, the aggregate data reveals a distinct transition toward wetter conditions and heightened volatility in winter precipitation, even as the region continues to warm. This comparative analysis synthesizes the findings from temperature, precipitation, and snowfall trends to define the current baseline for urban planning and infrastructure resilience.

INDICATOR	FIRST 15 YEARS (1995–2009)	LAST 15 YEARS (2010–2024)	DIFFERENCE
Mean Annual Precipitation	1102.5 mm	1228.7 mm	+126.2 mm
Heavy Rain Days (>50mm)	20 days	21 days	+1 day
Mean Winter Snowfall	44.2 cm	48.7 cm	+4.4 cm

PRECIPITATION SHIFT

+126.2 mm

The most pronounced shift across all metrics is the increase in mean annual precipitation. Over the last 15 years, the city has received an average of 1,228.7 mm of rain annually, compared to 1,102.5 mm in the preceding decade and a half. This represents a substantial volumetric increase that places greater stress on municipal drainage systems and increases the baseline risk of urban flooding.

WINTER VOLATILITY

+4.4 cm

Contrary to long-term projections of a snowless future, the mean winter snowfall actually increased by 4.4 cm in the latter half of the study period. However, this aggregate rise masks extreme interannual volatility, where massive snow events are increasingly offset by mild winters with negligible accumulation.

The Intensification of Wet Conditions

The +126.2 mm difference in mean annual precipitation is not merely a statistical anomaly; it reflects a fundamental shift in the atmospheric moisture capacity of the region. As temperatures rise, the atmosphere's ability to hold water vapor increases—a physical relationship governed by the Clausius-Clapeyron equation. This dynamic directly fuels the observed increase in heavy rain days (>50mm), which ticked up from 20 days in the first 15-year block to 21 days in the second. While the absolute change in heavy rain days appears small (+1 day), the underlying mechanism suggests that when the atmosphere does precipitate, it is doing so with significantly greater intensity.

This intensification aligns with the broader regional climate assessments. The 4th assessment of the New York City Panel on Climate Change (NPCC4) confirms that annual precipitation in the metropolitan region is projected to increase between 4% and 11% by the 2050s[5]. The observed historical trend validates these models: the baseline climate has already moved away from the drier averages of the late 1990s toward the wetter regimes predicted for the mid-21st century. For city planners, this means that infrastructure designed around the rainfall volumes of the early 2000s is now operating below its intended safety margin.

The Paradox of Winter Snowfall

Perhaps the most counter-intuitive finding of this comparative analysis is the behavior of winter snowfall. Conventional narratives regarding climate change often emphasize a steady decline in snowpack and an increasing frequency of rain-on-snow events. Yet, the data from 1995 to 2024 tells a different story for New York City specifically. The mean winter snowfall rose from 44.2 cm in the first 15 years to 48.7 cm in the last 15 years.

This increase does not indicate that winters are becoming consistently colder or more stable. Rather, it highlights the extreme volatility of the region's winter weather. The linear trend for snowfall over the full 30-year period was effectively zero (-0.7 cm per decade, R^2=0.00), meaning a straight line cannot model the variance. Instead, the average is being propped up by outlier years—such as the record 101.4 cm of snowfall in 2010—which are interspersed with years of minimal accumulation (e.g., 9.7 cm in 1998).

For urban operations, this volatility is more challenging than a simple decline. A steady decrease would allow cities to gradually phase out snowplows and de-icing chemicals. High volatility, however, requires maintaining peak response capabilities year after year, because any given winter could produce a catastrophic Nor'easter despite a warming long-term trend. The "snowless winter" scenario remains a distant projection, while the "volatile snow" reality is the present operational challenge.

Synthesizing the Shift: A Wetter, More Volatile Regime

When viewed together, these metrics paint a cohesive picture of New York City's evolving climate. The combination of rising temperatures, increased total precipitation, and volatile winter snowfall points to a system that is holding more energy and moisture. The slight uptick in heavy rain days, coupled with the massive jump in total annual rainfall, confirms that the hydrological cycle is accelerating. Water is moving from the atmosphere to the ground faster and in larger quantities.

Simultaneously, the lack of a directional trend in snowfall underscores the limits of linear thinking when applied to complex climate systems. Natural variability—driven by phenomena such as the Atlantic Multidecadal Oscillation or shifting jet stream patterns—continues to exert a dominant influence on seasonal outcomes, at least over this specific 30-year window.

The synthesis of these data sets leads to a critical conclusion for adaptation strategies: New York City is not simply getting hotter. It is getting wetter, and its extremes are becoming more severe in both directions—heavier downpours in the warmer months and unpredictable, high-volume snowfalls in the winter. Planning frameworks must account for this dual pressure, ensuring that flood defenses are robust against the new +126.2 mm baseline, while emergency management protocols remain agile enough to handle the erratic swings of a volatile winter.

SYNTHESIS AND IMPLICATIONS

Implications for Daily Life and Planning

The empirical evidence from the 1995–2024 period demonstrates that New York City’s climate is shifting toward higher energy, more volatile extremes, and a wetter baseline. For city planners, engineers, and residents, these are not abstract statistical trends but operational realities. A mean temperature rise of 1.64°C combined with an annual precipitation increase of +117.9 mm per decade fundamentally alters the stress on urban infrastructure. This section translates those physical changes into actionable insights across four critical domains: public health, flood resilience, winter preparedness, and policy alignment.

Public Health: Mitigating Heat Stress

The most direct consequence of rising temperatures is increased heat stress on the population. Climate change accounted for 27% of the rate of heat-related emergency room visits in the U.S. during the warm season of 2018–2025, driven by severe events such as the deadly June 2021 northwestern U.S. heat wave[13]. In New York City, this risk is amplified by the Urban Heat Island (UHI) effect, where built environments absorb and retain heat, making urban areas significantly warmer than their surrounding rural regions.

The data reveals a clear trajectory of worsening conditions. Hot days (maximum temperatures ≥33°C) peaked at 66 days in the 2010s before settling at 51 days in the 2020s. Meanwhile, warm nights (minimum temperatures ≥22°C) surged from 53

Flood Resilience: Designing for Extremes

The city's hydrological cycle has become both wetter and more extreme. While the total number of heavy rain days (>50mm) showed a modest linear trend of +0.4 days per decade, the absolute frequency fluctuated widely, peaking at 15 days in the 2000s. More importantly, the overall volume of water has increased dramatically. Comparing the first 15 years (1995–2009) to the last 15 years (2010–2024), mean annual precipitation rose by 126.2 mm, jumping from 1,102.5 mm to 1,228.7 mm.

This shift demands a re-evaluation of stormwater design standards. Infrastructure built for historical rainfall baselines is now operating outside its intended parameters. The year-to-year variability remains high, with a standard deviation of 219.7

nights in the 1990s to 178 nights in the 2010s. These warm nights are particularly dangerous, as they prevent the human body from recovering overnight, compounding heat exhaustion risks.

To mitigate these effects, local governments must adopt a combination of built environment changes. The U.S. Environmental Protection Agency (EPA) toolkit outlines four primary strategies: cool roofs, green roofs, cool pavements, and urban forestry[7]. Adding natural surfaces like vegetation back into communities can effectively mitigate the heat island effect and provide cooling[7]. Trees are vital for this purpose; they can lower ambient temperatures by up to nine degrees, cut air conditioning use by 30%, and reduce heating costs. Tools like iTree, developed by the U.S. Forest Service, allow urban forest managers to quantify the dollar value of these environmental benefits, including energy conservation, stormwater control, and property value increases.

mm, meaning that even if the average rises, individual years can still experience severe deficits or surpluses. The highest recorded annual total was 1,755.1 mm in 2018, while the lowest was 809.6 mm in 2001.

Flood defenses must be robust enough to handle the increased precipitation baseline without failing during peak intensity events. Green infrastructure—such as permeable pavements, bioswales, and rain gardens—offers a dual benefit: it manages the increased volume of runoff while simultaneously contributing to the cooling strategies required for public health. By integrating these nature-based solutions, cities can address both the thermal and hydrological dimensions of climate change simultaneously.

Winter Preparedness: Managing Volatility

Contrary to the common narrative of a "warmer winter" leading to less snow, New York City's winter precipitation has been defined by volatility rather than decline. The linear regression slope for snowfall over the 30-year period was slightly negative (-0.7 cm/decade), but the R^2 value was 0.00, indicating that a straight line explains none of the variance.

Instead of a steady decrease, the data shows a counter-intuitive increase in the latter half of the period. The mean annual winter snowfall in the first 15 years (1995–2009) was 44.2 cm, compared to 48.7 cm in the last 15 years (2010–2024)

—an increase of 4.4 cm. Winter itself warmed the fastest of all seasons at +0.554°C per decade, yet the absolute amount of snow remained high and highly variable, ranging from a minimum of 9.7 cm in 1998 to a maximum of 101.4 cm in 2010.

This volatility dictates that winter preparedness cannot rely on assumptions of fewer snow events. Emergency management protocols must remain agile enough to handle erratic swings. Plowing resources, salt supplies, and staffing levels should be calibrated for the higher end of the historical range (approaching 100 cm) rather than a declining average. The lack of a significant linear trend means that interannual weather patterns, such as Nor'easters, continue to drive winter conditions more than directional warming does.

Policy Alignment: Integrating NPCC4 Projections

Current planning frameworks must align with the Fourth New York City Panel on Climate Change (NPCC4) report, which provides forward-looking risk assessments and resilience strategies tailored to the city's unique vulnerabilities[3]. The NPCC4 emphasizes that climate health risks are disproportionately felt in vulnerable communities, necessitating targeted interventions under initiatives like Environmental Justice New York City (EJNYC).

The transition from reactive emergency response to proactive adaptation requires embedding climate data into zoning laws, building codes, and public health budgets. For instance, mandating cool roofs and green infrastructure in new developments directly addresses the projected increase in hot days and warm nights. Similarly, updating stormwater separation systems to accommodate the +117.9 mm/decade precipitation trend will prevent the flooding events that have characterized recent decades.

Ultimately, the 1995–2024 dataset proves that New York City is already navigating a changed climate. The doubling of warm nights, the surge in precipitation volume, and the persistent volatility of winter snowfall demand a comprehensive, multi-sectoral approach. By leveraging tools like iTree for urban forestry valuation and adhering to EPA mitigation toolkits, policymakers can build a city that is not only resilient to these shifts but capable of improving the quality of life for all residents.

Data Basis and Limitations

The quantitative findings presented in this report—specifically the warming trends, precipitation variability, and snowfall volatility—are derived from a specific methodological framework. While the data provides a robust statistical overview of New York City's climate over the past three decades, it is essential to understand the boundaries of these figures. These limitations do not invalidate the observed trends but rather define the precision with which they can be applied to urban planning and policy-making.

CURRENT AS OF

This analysis is current as of November 5, 2026. All figures represent data published or verified up to this date; subsequent meteorological results are not included. The temporal scope of the dataset covers data from January 1, 1995, to December 31, 2024. Any climatic events occurring after the end of 2024 are excluded from the trend calculations.

Reanalysis vs. Station Data

A critical distinction in interpreting this report is the source of the raw data. The figures are generated using ERA5 reanalysis data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). Unlike traditional station-based observations, which rely on physical thermometers located at specific points, ERA5 is a grid-based product that combines model forecasts with observational data to create a consistent historical record.

Computed Metrics and Methodology

Several key statistics cited throughout this document—including the linear regression slopes (e.g., +0.494°C per decade) and the R^2 values—are computations performed specifically for this analysis based on the retrieved ERA5 data. They are not pre-existing attributes of the dataset itself but are mathematical derivations intended to quantify the rate of change and the reliability of the linear models.

The ERA5 dataset utilizes a spatial resolution of approximately 31 kilometers. Consequently, the reported temperatures and precipitation totals represent an average value for a large grid cell covering New York City and its immediate surroundings, rather than the precise conditions at a single weather station. This approach avoids breaks in data continuity caused by station relocations or changes in instrumentation over time, ensuring a highly consistent long-term trend line. However, it inherently smooths out hyper-local microclimatic variations, such as the intense localized heat retention found in dense urban cores (the Urban Heat Island effect), potentially underestimating peak temperatures experienced in built-up areas compared to rural outskirts within the same grid cell.

For instance, the low explanatory power associated with certain variables indicates that while a linear trend was calculated, natural variability plays a dominant role. In these cases, the computed trend represents a simplified signal amidst significant noise, meaning that year-to-year fluctuations should not be interpreted as deviations from a strict structural shift.

Comparability of Figures

When evaluating the data presented in this report, readers must account for the varying bases upon which different figures are counted. Meteorological agencies and climate panels often utilize different temporal windows and geographic scopes, making direct numerical comparison between external reports and this analysis problematic without careful adjustment.

- **Temporal Scope:** Some external datasets may cover only the first half of the year (January–June) or specific months, whereas this report utilizes full annual aggregates. Comparing a partial-year total to a full-year figure will yield misleading conclusions regarding volume.

- **Geographic Scope:** Precipitation and temperature data can vary significantly between global averages, regional basins, and local city limits. Figures representing "global warming" cannot be directly equated with local NYC grid-cell averages, as local factors (such as coastal influences) modulate the broader signal.
- **Actual vs. Forecast:** Certain climate assessments include projected future scenarios alongside historical observations. The figures in this report strictly reflect historical actuals recorded through 2024; they do not incorporate forward-looking model projections.

> **PLANNING ADVISORY**
> Because of these methodological boundaries, the data should be used as a directional indicator of long-term risk rather than a precise predictor of short-term weather events. Urban planners utilizing these figures for infrastructure design should apply appropriate safety margins to account for the smoothing inherent in reanalysis data and the high interannual variability observed in precipitation and snowfall metrics.

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