# APPENDIX B

## Technical Memorandum on the EPA Supplemental Proposal's Reliance on Global Average Temperature and Sea Level Rise Metrics

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### I. Introduction

This technical memorandum supports the joint comments filed by Public Health and Environmental Organizations on EPA's proposed supplemental rulemaking entitled "Rescission of the Greenhouse Gas Findings for Fossil Fuel-Fired Power Plants and Repeal of Regulations for Power Plant Greenhouse Gas Emissions Under Clean Air Act Section 111," 91 Fed. Reg. 59,002 (Sept. 17, 2026). This memo examines how EPA's recent use of global mean surface temperature (GMST) and global mean sea level (GMSL) as the only metrics to assess the impacts of climate change is contrary to the scientific consensus which shows that seemingly "small" increases in GMST and GMSL translate into profound, non-linear, and compounding[1] risks for the human health and welfare of people in the United States. We highlight that: (1) global mean temperatures and global mean sea level rise do not account for regional variations in the U.S., which in many cases are much higher than global averages; (2) global annually-averaged temperatures mask true risks to people's health and well-being because they fail to take into account climate-driven temperature extremes such as heatwaves, which are increasing in frequency and duration and are a known driver of climate-related morbidity and mortality; (3) overlapping climate impacts, such as heat, drought and wildfire, or storm surge from intensified tropical storms riding on higher sea levels, can lead to compounding and cascading impacts that magnify risks to people's health and welfare—interactions that are often obscured by solely focusing on mean global surface temperature and sea level values; (4) recent science indicates an acceleration in global warming, demonstrating that relying on past averages may not be a good predictor of future risks from additional greenhouse gas emissions, and (5) recent science also indicates exceptional ocean warming which also has profound implications for conditions on land in the United States and around the world.

Drawing on recent data, scientific reports, and peer-reviewed literature, we demonstrate that global averages obscure critical regional disparities that impact communities and economies across the country. For example, the U.S. East and Gulf Coasts are experiencing accelerating sea-level rise rates that significantly exceed the global mean due to ocean dynamic changes and land

[1] Deepti Singh et al., *Focus on compound events*, *in Fifth National Climate Assessment* (A.R. Crimmins et al. eds., U.S. Global Change Rsch. Prog. 2023).

subsidence.[2,3] A recent study shows that attributable sea level in Charleston, South Carolina—which has experienced higher sea level rise (SLR) than the global average—has been "dominated over time by contributions from mountain glaciers and thermal expansion," both factors that are related to human-caused climate change.[4]

Simultaneously, many regions of the United States are warming faster than the global average, such as arctic Alaska, which has warmed at nearly three times the global rate since 1980,[5] driving cascading ecological and infrastructural failures.[6] New England in the Northeast U.S. is also warming much more and faster than most parts of the world.[7,8] Because of climate change, every U.S. congressional district has warmed since 1970, by an average of 2.8°F, with the fastest warming districts in Alaska (4.8°F) and the Southwest (an average of 3.2°F), followed by districts in the Upper Midwest (an average of 2.9°F).[9,10]

Furthermore, reliance on GMST and GMSL metrics fails to capture the intensification of local extreme weather events—hurricanes, droughts, and floods—which serve as the primary vectors

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[2] Christopher G. Piecuch, *The Rate of U.S. Coastal Sea-Level Rise Doubled in the Past Century*, 6 AGU Advances e2025AV002018 (2025), https://doi.org/10.1029/2025AV002018.

[3] William V. Sweet et al., Nat'l Oceanic & Atmospheric Admin., *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (2022).

[4] Daniel M. Gilford et al., *Human-caused sea level rise drives 21st-century worldwide water level extremes*, 12 Sci. Advances 4 (2026), 10.1126/sciadv.adz3595.

[5] Thomas J. Ballinger et al., *Surface Air Temperature, in Nat'l Oceanic & Atmospheric Admin., Arctic Report Card: Update for 2025* (Matthew L. Druckenmiller et al. eds., 2025), https://arctic.noaa.gov/report-card/report-card-2025/

[6] M. L. Druckenmiller, R. L. Thoman, & T. A. Moon, *NOAA Arctic Report Card 2025: Executive Summary* (2025), https://doi.org/10.25923/nrzf-j897.

[7] Stephen S. Young & Joshua S. Young, *Decreasing Snow Cover and Increasing Temperatures Are Accelerating in New England, USA, with Long-Term Implications*, 13 Climate 246 (2025), https://doi.org/10.3390/cli13120246.

[8] Ambarish V. Karmalkar & Radley M. Horton, *Drivers of Exceptional Coastal Warming in the Northeastern United States*, 11 Nature Climate Change 854 (2021), https://doi.org/10.1038/s41558-021-01159-7.

[9] Climate Central, *Fastest-Warming U.S. Congressional Districts* (2026), https://www.climatecentral.org/climate-matters/fastest-warming-congressional-districts.

[10] Daniel M. Gilford et al., *A Multi-Method Framework for Global Real-Time Climate Attribution*, 8 Advances in Stat. Climatology, Meteorology & Oceanography 135 (2022), https://doi.org/10.5194/ascmo-8-135-2022.

for health impacts and economic disruption from climate change.[11,12,13,14] Studies also show that compounding and cascading climate risks, including those from extreme heat and sea level rise, worsen impacts on human health infrastructure and the economy.[15,16] **We argue that relying solely on global averages is a fundamentally flawed way to estimate the threat to the health and welfare of people in the U.S. and the benefits of limiting those threats.**

## II. Limitations of Averaging Over Spatial Scales

The most significant flaw in using global averages to assess U.S. risk is the assumption of uniformity with regards to both GMST and GMSL. Sea level is not a flat bathtub that rises evenly everywhere.[17,18] It is a dynamic surface influenced by gravity, ocean currents, wind patterns, and vertical land motion. Further complicating this, the relationship between sea level and temperature is non-linear, and the rate of SLR has been accelerating faster than previously

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[11] Kai Kornhuber et al., *Global Emergence of Regional Heatwave Hotspots Outpaces Climate Model Simulations*, 121 Proc. Nat'l Acad. Scis. e2411258121 (2024), https://doi.org/10.1073/pnas.2411258121.

[12] Richard W. Katz & Barbara G. Brown, *Extreme Events in a Changing Climate: Variability Is More Important than Averages*, 21 Climatic Change 289 (1992), https://doi.org/10.1007/BF00139728.

[13] Adam B. Smith, *U.S. Billion-Dollar Weather and Climate Disasters, 1980 - Present (NCEI Accession 0209268)*, NOAA Nat'l Ctrs. for Env't Info. (2020), https://doi.org/10.25921/STKW-7W73.

[14] Melanie Marino, Matthew J. Eckelman, & Jodi D. Sherman, *Commonwealth Fund State Scorecard on Climate, Health, and Health Care* (2025), https://doi.org/10.26099/8K6M-5D55.

[15] Taejin Park et al., *What Does Global Land Climate Look Like at 2°C Warming?*, 11 Earth's Future e2022EF003330 (2023), https://doi.org/10.1029/2022EF003330.

[16] Kristie L. Ebi, *Understanding the Risks of Compound Climate Events and Cascading Risks*, 2 Dialogues on Climate Change 33 (2025), https://doi.org/10.1177/29768659241304857.

[17] NASA Sea Level Change, *Are Sea Levels Rising the Same All over the World, as If We're Filling a Giant Bathtub?*, https://sealevel.nasa.gov/faq/9/are-sea-levels-rising-the-same-all-over-the-world-as-if-were-filling-a-giant-bathtub/ (last visited Oct. 26, 2026).

[18] John T. Fasullo & R. Steven Nerem, *Altimeter-Era Emergence of the Patterns of Forced Sea-Level Rise in Climate Models and Implications for the Future*, 115 Proc. Nat'l Acad. Scis. 12944 (2018), https://doi.org/10.1073/pnas.1813233115.

projected due to thermal expansion and accelerating land ice loss.[19] Consequently, the U.S. coastline is experiencing rates of change that diverge sharply from the global mean (Fig. 1).[20,21]

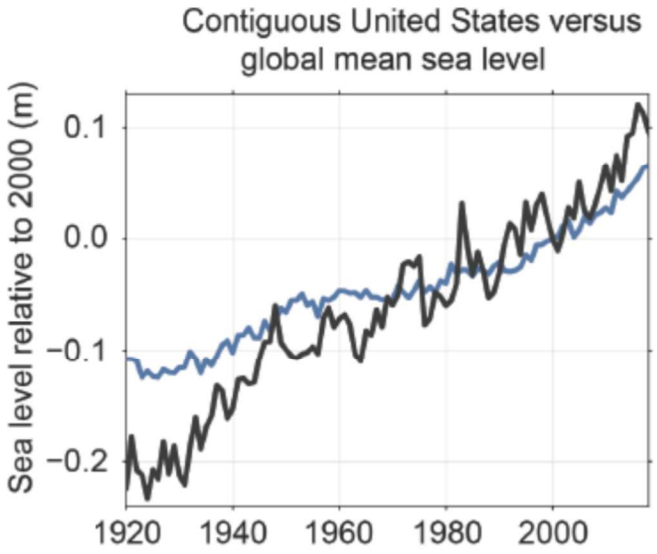



**Figure 1 -** GMSL change (blue line) as shown in a) with the annual average relative sea level change measured by tide gauges around the contiguous United States (black line; with a linear regression estimate of 28 cm of sea level rise from 1920 to 2020). Data and figure adapted from NOAA's 2022 report, Global and Regional Sea Level Rise Scenarios for the United States (Fig. 1.2) and Frederikse et al. 2020.[22,23]

[19] Sweet et al., *supra*.

[20] Fasullo & Nerem, *supra.*

[21] Christine L. May et al., *Coastal Effects, in Fifth National Climate Assessment* ch. 9 (Allison R. Crimmins et al. eds., U.S. Global Change Rsch. Prog. 2023), https://doi.org/10.7930/NCA5.2023.CH9.

[22] Sweet et al., *supra.*

[23] Thomas Frederikse et al., *The Causes of Sea-Level Rise since 1900*, 584 Nature 393 (2020), https://doi.org/10.1038/s41586-020-2591-3.

**Accelerated Sea Level Rise on the East and Gulf Coasts**

Recent analysis on sea level rise for U.S. coastal communities shows that the East and Gulf Coasts are consistently hotspots for sea-level rise.[24,25,26] A 2025 study by the Woods Hole Oceanographic Institution found that the rate of relative sea-level rise—measured relative to the local land surface—along the U.S. coast has more than doubled in the past 125 years, increasing from approximately 1.7 millimeters per year in 1900 to over 4.3 millimeters per year in 2024.[27] This rate is well above the global average for sea-level rise **of ~3.1 mm/year** observed in recent decades.[28]

The William & Mary Virginia Institute of Marine Science 2024 Sea Level Report Cards, which analyze data from 36 U.S. coastal communities, confirm this acceleration which can be compared to the global average. The report cards show that sea level rise acceleration rates began increasing notably around 2013-2014 along the East and Gulf Coasts.[29] Most sea level projections are based on an understanding of average global sea level rise, but these local report cards demonstrate that the reality for U.S. coastal communities diverges significantly from global averages due to regional factors. Along the East and Gulf Coasts, land subsidence, changes in ocean currents, and glacial isostatic adjustment create hotspots where relative sea level rise can exceed global averages. For instance, Grand Isle, Louisiana, is currently experiencing a rise rate of 7.72 mm/year, while Rockport, Texas, and Norfolk, Virginia, face rates of 6.71 mm/year and 5.14 mm/year, respectively—far outpacing the global mean of approximately 3.1 mm/year.[30,31] Other regions may experience slower rates. Such spatial variability means communities face divergent risks that global averages and projections do not capture.

**Disproportionate Warming Rates**

Many regions of the U.S. are experiencing disproportionate warming rates compared to the

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[24] John D. Boon et al., *Anthropocene Sea Level Change: A History of Recent Trends Observed in the U.S. East, Gulf, and West Coast Regions* (Special Rep. in Applied Marine Sci. & Ocean Eng'g No. 467, 2018), https://doi.org/10.21220/V5T17T; *see also* Va. Inst. of Marine Sci., *U.S. Sea Level Report Cards: Trends, Projections, and Process to Aid Coastal Planning*, https://www.vims.edu/research/products/slrc/.

[25] Asbury H. Sallenger Jr. et al., *Hotspot of Accelerated Sea-Level Rise on the Atlantic Coast of North America*, 2 Nature Climate Change 884 (2012), https://doi.org/10.1038/nclimate1597.

[26] Sweet et al., *supra.*

[27] Piecuch, *supra*.

[28] Sweet et al., *supra.*

[29] Boon et al., *supra*.

[30] Sweet et al., *supra.*

[31] Boon et al., *supra*.

global average. For most years since the 1970s, the average surface temperature in the U.S. has risen faster than the global average temperature.[32,33] The 5th U.S. National Climate Assessment states that the continental U.S. has warmed 60% faster than the global average since 1970,[34] exceeding the 1991-2020 average by 0.8°C in 2025.[35] This is in part due to land areas warming faster than oceans, but it also results from regional climate dynamics. This means that the historical and projected warming that Americans experience where they live is inherently higher than the 'global average' temperatures commonly reported (Fig. 2).

For example, Alaska is warming significantly faster than the global average (Fig.2).[36] This phenomenon is called arctic amplification and is driven by the loss of reflective sea ice and snow that drives the Arctic region to warm significantly faster than the global average. When bright, reflective ice melts, it exposes darker ocean waters that absorb more heat from the sun, creating a feedback loop that accelerates warming. The smallest peak sea ice extent in the 47-year satellite record occurred in March 2025.[37]

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[32] EPA, *Climate Change Indicators in the United States*, EPA 430-R-24-003 (5th ed. 2024), www.epa.gov/climate-indicators.

[33] Alexa K. Jay et al., *Overview: Understanding risks, impacts, and responses*, *in Fifth National Climate Assessment* ch. 1 (Allison R. Crimmins et al. eds., U.S. Global Change Rsch. Prog., 2023).

[34] Kate Marvel et al., *Climate Trends*, *in Fifth National Climate Assessment*, ch. 2 (Allison R. Crimmins et al. eds., U.S. Global Change Rsch. Prog., 2023), https://doi.org/10.7930/NCA5.2023.CH2.

[35] *Regional Climates*, *in State of the Climate in 2025*, 107 Bull. Am. Meteorological Soc'y S401 (A. Arguez et al. eds. 2026), https://doi.org/10.1175/2026BAMSStateoftheClimate_Chapter7.1.

[36] Climate Central, *supra*.

[37] NOAA in the Arctic, *Arctic Report Card: Update for 2025* (2025), https://arctic.noaa.gov/report-card/report-card-2025/.

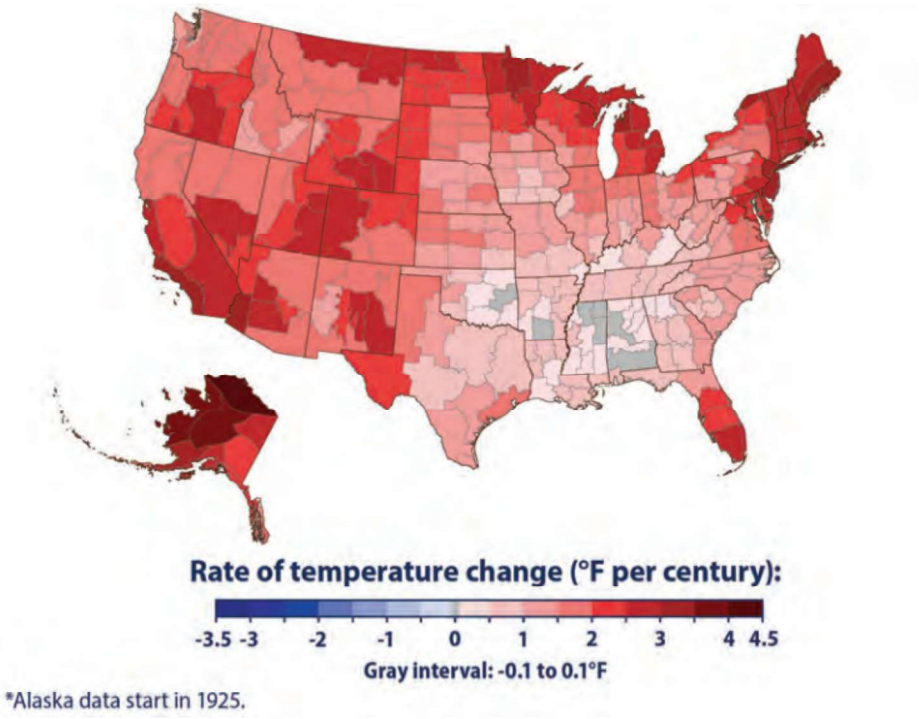



**Figure 2 –** Rate of Temperature change in the U.S. between 1901 and 2023 for the contiguous 48 states and between 1925 and 2023 for Alaska. The data are shown for climate divisions, as defined by NOAA.[38]

Findings from the 2025 *Arctic Report Card*, released by NOAA, confirm that the Arctic, globally, has warmed nearly three times faster than the rest of the planet since 1980.[39] For the period of October 2024 through September 2025, the Arctic experienced its warmest temperatures on record since measurements began in 1900. The last ten years in the Arctic are the ten warmest on record, with annual temperatures increasing at more than double the global rate since 2006 (Fig. 3).[40]

The Alaska Climate Research Center reported 2025 as one of Alaska's warmest years in the past 100, with northern Alaska exhibiting warming consistent with this broader Arctic pattern.[41] Elevated temperatures throughout the year contributed to diminished spring snowpack, earlier

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[38] EPA, *Climate Change Indicators in the United States*, *supra*.

[39] Ballinger et al., *supra*.

[40] NOAA in the Arctic, *Arctic Report Card: Update for 2025* (2025), https://arctic.noaa.gov/report-card/report-card-2025/.

[41] Alaska Climate Rsch. Ctr., *2025 Annual Report* (2025), https://akclimate.org/data/annual-reports/.

snowmelt, and increased wildfire risk, with Interior Alaska experiencing the most pronounced effects.[42]

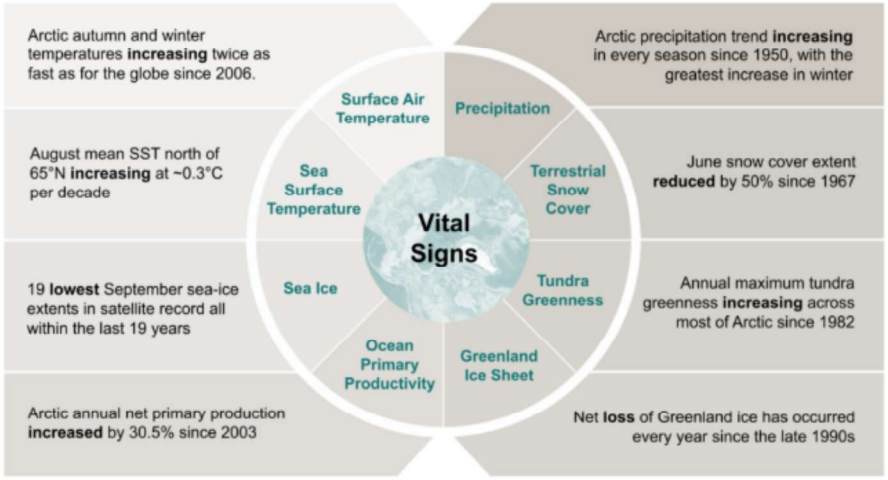



**Fig. 1. Arctic Report Card Vital Signs with selected noteworthy trends and observations.** The ARC annually reports on eight Vital Sign topics. Vital Sign data records vary in length based on dataset availability and considerations to methodological continuity. The historical record periods are used when computing ranked observations. When reporting anomalies, Vital Signs currently use 1991-2020 as the 30-year reference period, except for Tundra Greenness (2000-24) and Ocean Primary Productivity (2003-24).

**Figure 3 -** Summary of key Arctic "Vital Signs" showing major environmental changes. Indicators include temperature, precipitation, snow cover, sea ice, ocean productivity, tundra greenness, and the Greenland Ice Sheet. Overall, the Arctic is warming rapidly, with declining ice and snow and increasing precipitation and vegetation.[43]

Another example is in the U.S. Northeast, the fastest warming region in the contiguous U.S.[44] Many Northeast states including Maine,[45] New Jersey,[46] and Rhode Island,[47] have had a 3°F

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[42] Alaska Climate Rsch. Ctr., *2025 Alaska Annual Climate Report* (2026), https://akclimate.org/data/annual-reports/.

[43] NOAA in the Arctic, *Arctic Report Card: Update for 2025* (2025), https://arctic.noaa.gov/report-card/report-card-2025/.

[44] Ambarish V. Karmalkar & Raymond S. Bradley, *Consequences of Global Warming of 1.5 °C and 2 °C for Regional Temperature and Precipitation Changes in the Contiguous United States*, 12 PLOS ONE e0168697 (2017), https://doi.org/10.1371/journal.pone.0168697.

[45] Maine Climate Council Sci. & Tech. Subcomm., *Scientific Assessment of Climate Change and Its Effects in Maine* 8 (Ivan Fernandez & Robert Marvinney eds. 2020).

[46] Kathryn Davies et al., *State of the Climate: New Jersey 2024* (2025), https://doi.org/10.7282/00000539.

[47] Jennifer Runkle et al., *Rhode Island State Climate Summary 2022*, NOAA Technical Report NESDIS 150-RI (2022).

(~1.7°C) to 4°F (~2.2°C) increase in their average temperature since the early 20th Century, nearly twice the rate of global average warming. Studies attribute this amplified regional warming to a combination of anthropogenic-influenced factors: rapid ocean warming across the Northeast continental shelf and consequent regional atmospheric circulation changes,[48] decreasing snow cover that amplify land-warming,[49] and the disproportionate warming of nighttime and winter temperatures relative to daytime and summer temperatures at higher latitudes.[50]

## III. Limitations of Averaging Over Temporal Scales

There are also limitations when averaging GMST and GMSL over temporal scales to assess U.S. risk. Mean temperatures alone cannot capture changes in extremes; extremes are impacted by changes to their mean and distribution. Therefore, averaging GMST over a specific time-period may not account for the distributional shifts of extreme events over that period. In fact, data show that GMST masks the increase in heat-related extremes, including multi-day heatwaves, which are consequential for heat-related adverse health outcomes.[51]

For example, in the United States, the annual number of heatwaves has doubled since the 1980s and the heatwave season has increased threefold in length since the 1960s.[52] A recent study of heat-related mortality among older adults in the United States drives home the disproportionate consequences of climate impacts, finding: "Heat waves are associated with a substantial increase in annual all-cause and cause-specific mortality among older adults in the USA, with disproportionate impacts on Black and low income communities."[53] According to the study, "[a]cross the contiguous USA from 2000–18, the 8307 observed heat waves were associated with an estimated 17603 . . . excess deaths."[54]

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[48] Karmalkar & Horton, *supra*.

[49] Young & Young, *supra*.

[50] Marvel et al., *supra.*

[51] Ali Davariashtiyani et al., *Exponential Increases in High-Temperature Extremes in North America*, 13 Sci. Rpts. 19177 (2023), https://doi.org/10.1038/s41598-023-41347-3.

[52] Michelle L. Bell, Antonio Gasparrini & Georges C. Benjamin, *Climate Change, Extreme Heat, and Health*, 390 New Engl. J. Med. 1793 (2024), https://doi.org/10.1056/NEJMra2210769.

[53] James P. Healy et al., *Heat Waves and Annual Mortality among Older Adults (Aged ≥65 Years) in the USA*, 10 The Lancet Planetary Health 101432 (2026), https://doi.org/10.1016/j.lanplh.2026.101432.

[54] Healy et al., *supra.*

Similarly, since 1993, global sea level has risen by 4 inches[55] (10 centimeters), and the rate of rise has doubled over the past 30 years (Fig. 4).[56,57] In 2024, global sea level rose at a rate of 0.23 inches (0.59 cm) per year, more than 30% more than the projected rate of 0.17 inches (0.43 cm).[58] According to a NASA-led analysis, this spike was driven largely by thermal expansion—the physical expansion of seawater as it warms. In a typical year, melting ice contributes the majority of sea-level rise, with thermal expansion accounting for about one-third. However, in 2024, as the warmest year on record, this ratio flipped: two-thirds of the rise came from thermal expansion.[59] **This phenomenon illustrates that the relationship between temperature and sea level is not static over space or time**. As the ocean absorbs excess heat, the water expands. Even a "small" average temperature increase in the upper ocean layers results in a measurable, accelerating rise in sea level.

Furthermore, temperature and sea-level exhibit time-dependent responses; temporal averaging of GMST and GMSL dampens their evolving relationships, feedbacks, and underlying dynamics.

[55] Jane J. Lee, *NASA Analysis Shows Unexpected Amount of Sea Level Rise in 2024*, NASA Sea Level Change (Mar. 13, 2025), https://sealevel.nasa.gov/news/282/nasa-analysis-shows-unexpected-amount-of-sea-level-rise-in-2024/.

[56] Benjamin D. Hamlington et al., *Sea Level Rise in 2024*, 6 Nature Revs. Earth & Env't 246 (2025), https://doi.org/10.1038/s43017-025-00667-w.

[57] Benjamin D. Hamlington et al., *The Rate of Global Sea Level Rise Doubled during the Past Three Decades*, 5 Commc'ns Earth & Env't 601 (2024), https://doi.org/10.1038/s43247-024-01761-5.

[58] Lee, *supra*.

[59] Lee, *supra*.

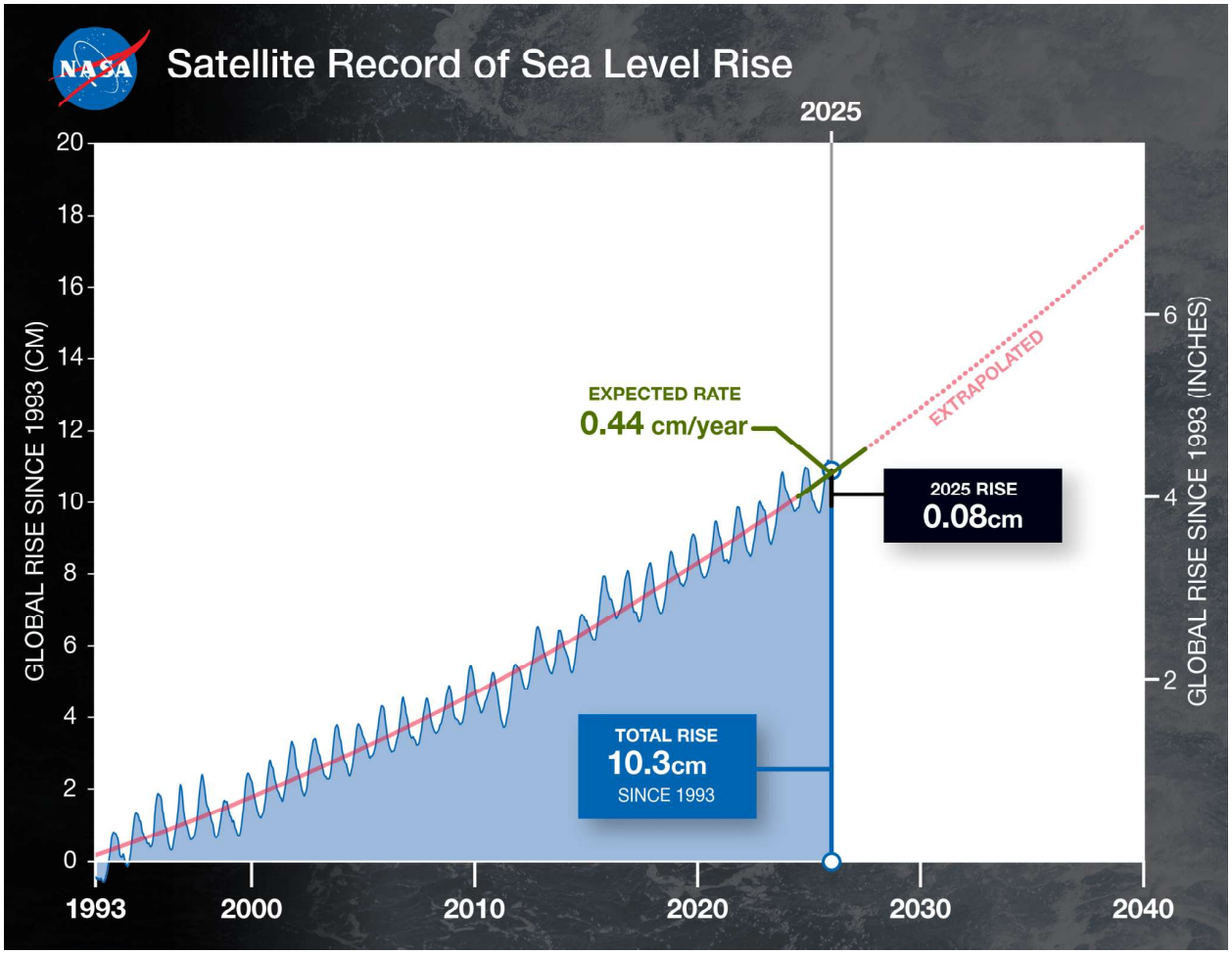



**Figure 4 –** Satellite-derived record of global mean sea level rise from 1993 to 2025 as measured by five satellites. The blue curve shows observed sea level change with seasonal variability, while the solid red line indicates the long-term trend, which has accelerated over time and more than doubled over three-plus decades. By 2025, global sea level has risen approximately 10.3 cm (about 4 inches) since 1993. The dotted red line represents extrapolated future rise, compared with an expected rate of 0.44 cm (about 0.17 inches) per year. (Source: NASA/JPL-Caltech).[60]

Furthermore, recent studies indicate that the GMST increase is accelerating, a non-linearity that, if ignored, risks understating future risks from additional greenhouse gas emissions.[61] Since the 1970s, GMST has been increasing at an average rate of 0.2°C/decade. Since the 2010s, the average rate is about 0.25-0.40°C/decade. The acceleration also suggests we will breach the 1.5°C global warming threshold sooner than expected, with estimations of breaching it within

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[60] NASA, *NASA Analysis Shows La Niña Limited Sea Level Rise in 2025* (Jan. 29, 2026), https://www.nasa.gov/earth/nasa-analysis-shows-la-nina-limited-sea-level-rise-in-2025/.

[61] Grant Foster & Stefan Rahmstorf, *Global Warming Has Accelerated Significantly*, 53 Geophysical Rsch. Letters e2025GL118804 (2026), 10.1029/2025GL118804.

this decade.[62] A breach of this threshold this soon has major implications for existing risk assessments for extreme weather, irreversible land glacial ice loss, and Earth-System tipping points that could become irreversible. Ignoring this acceleration and non-linear behavior of GMST risks failing to accurately understand when these impacts could occur and limits the ability to predict these changes.

## IV. Limitations of Ignoring Non-Linearities

### Limitations of Global Mean Metrics in Assessing Regional Climate Risk

In regulatory and policy discourse, descriptions of climate change that focus solely on increases in GMST and GMSL can misrepresent these changes as manageable despite strong evidence that small increments of change in global averages trigger disproportionate and potentially disruptive changes in regional climate dynamics, extreme weather frequency and/or intensity, and ecosystem stability. Many climate systems are non-linear, and the impacts of climate change are not distributed evenly across the globe.[63,64,65,66] Domestic regulatory policies must account for the discrepancy between global average impacts and the local reality for Americans. While the globe, on average, may warm by one margin, parts of the U.S. are experiencing temperature changes that are two to three times more severe.[67,68] Similarly, while global average sea levels rise at a seemingly moderate pace, specific American coastlines are facing accelerated flooding

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[62] U.N. Env't Prog., *Limiting Overshoot: Navigating exceedance of 1.5°C and pathways towards return* 13 (2026), https://doi.org/10.59117/20.500.11822/49857.

[63] Shaina Sadai et al., *Antarctic Meltwater Alters Future Projections of Climate and Sea Level*, 16 Nature Commc'ns 9271 (2025), https://doi.org/10.1038/s41467-025-64438-3.

[64] María Dolores Gadea Rivas & Jesús Gonzalo, *Regional Heterogeneity and Warming Dominance in the United States*, 5 PLOS Climate e0000808 (2026), https://doi.org/10.1371/journal.pclm.0000808.

[65] Young & Young, *supra*.

[66] Climate Central, *Earth Day: Fastest-Warming U.S. Cities and States* (Apr. 16, 2025), https://www.climatecentral.org/climate-matters/earth-day-fastest-warming-us-cities-and-states#cm-license.

[67] Druckenmiller et al., *supra*.

[68] Young & Young, *supra*.

and inundation that threaten critical infrastructure, public health, and economic stability much sooner than global models suggest.[69,70,71,72]

The relationship between GMST and extreme weather frequency and/or intensity is governed by non-linear dynamics in the climate system. Incremental increases in atmospheric and oceanic heat content produce disproportionate changes in the distribution of weather events, such as elevated probabilities of extreme events relative to baseline conditions.[73] This phenomenon is well-documented in peer-reviewed literature, where small shifts in mean temperature correspond to non-linear increases in the frequency of threshold-exceeding events, including heat waves, heavy precipitation, drought conditions, and hydroclimate volatility.[74,75,76,77]

The impact of sea-level rise on flooding is often exponential, not linear. As noted in peer-reviewed research, a small increase in the baseline sea level dramatically increases the frequency of high-tide flooding.[78,79] What was once a 1-in-100-year flood event can become a 1-in-10-year

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[69] Piecuch, *supra.*

[70] Sönke Dangendorf et al., *Acceleration of U.S. Southeast and Gulf Coast Sea-Level Rise Amplified by Internal Climate Variability*, 14 Nature Commc'ns 1935 (2023), https://doi.org/10.1038/s41467-023-37649-9.

[71] Elisabeth A. Gilmore, Carolyn Kousky & Travis St.Clair, *Climate Change Will Increase Local Government Fiscal Stress in the United States*, 12 Nature Climate Change 216 (2022), https://doi.org/10.1038/s41558-022-01311-x.

[72] Miyuki Hino et al., *High-Tide Flooding Disrupts Local Economic Activity*, 5 Sci. Advances eaau2736 (2019), https://doi.org/10.1126/sciadv.aau2736.

[73] Sonia I. Seneviratne et al., *Weather and Climate Extreme Events in a Changing Climate, in Intergovernmental Panel on Climate Change, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report* ch. 11 (Valérie Masson-Delmotte et al. eds., 2021), https://doi.org/10.1017/9781009157896.013.

[74] Noah S. Diffenbaugh & Filippo Giorgi, *Climate Change Hotspots in the CMIP5 Global Climate Model Ensemble*, 114 Climatic Change 813 (2012), https://doi.org/10.1007/s10584-012-0570-x.

[75] Seneviratne et al., *supra*.

[76] Daniel L. Swain et al., *Hydroclimate Volatility on a Warming Earth*, 6 Nature Revs. Earth & Env't 35 (2025), https://doi.org/10.1038/s43017-024-00624-z.

[77] Linda O. Mearns, Richard W. Katz & Stephen H. Schneider, *Extreme High-Temperature Events: Changes in Their Probabilities with Changes in Mean Temperature*, 23 J. Climate & Applied Meteorology 1601 (1984), https://doi.org/10.1175/1520-0450(1984)023<1601:EHTECI>2.0.CO;2.

[78] Sean Vitousek et al., *Doubling of Coastal Flooding Frequency within Decades Due to Sea-Level Rise*, 7 Sci. Rpts. 1399 (2017), https://doi.org/10.1038/s41598-017-01362-7.

[79] Sweet et al., *supra.*

event with only a few inches of rise. Sea level acts as a rising floor, such that storm surges and high tides start from a higher baseline, allowing them to breach defenses that were previously sufficient.

Research published in *Scientific Reports* demonstrated that along most of the U.S. coast, the odds of extreme flooding double roughly every five years due to sea-level rise, even without increases in storm intensity.[80,81] This research highlights how even 10 cm of SLR doubles flooding potential along the west coast of the US, including Seattle, San Francisco, and Los Angeles,[82] highlighting that the "magnitude" of the rise is less relevant than the "frequency" of the resulting impact. A rise of a few inches can double or triple the number of days a coastal community is inundated, leading to chronic infrastructure degradation, mold growth in homes, and disruption of local economies. Related research highlights how even smaller amounts of sea level rise, between 1 and 10 cm, can lead to outsized impacts by increasing the frequency of coastal floods.[83] This underscores why looking at GLSR alone is not sufficient to understand how that change will impact Americans.

**Regional Variation in Extreme Weather Event Trends**

A focus on only GMST and GSLR fails to account for how changes in those metrics will lead to more frequent and intense extreme weather, the primary way that climate change harms human health and welfare. Americans do not experience "global averages"; they experience hurricanes, droughts, rainfall, heatwaves, wildfires, and floods. Climate change is contributing to the increase in frequency, duration, and/or intensity of these types of events, regardless of the magnitude of the shift in global averages. For example, data show that heatwaves are increasing in frequency and duration, especially in the western U.S. and Southeast.[84] These extreme events are not random; they are symptomatic of a changing climate, which is not fully captured by expressions of global mean temperatures.

In 2024, the U.S. experienced 27 separate extreme weather and climate disasters with costs exceeding $1 billion each (Fig. 5).[85] Over the last decade (2015–2024), the U.S. has been impacted by 190 such disasters, costing approximately $1.4 trillion and killing more than 6,300

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[80] Sweet et al., *supra.*

[81] Mohsen Taherkhani et al., *Sea-level rise exponentially increases coastal flood frequency*, 10 Sci. Rep. 6466 (2020), https://doi.org/10.1038/s41598-020-62188-4.

[82] Vitousek et al., *supra.*

[83] Taherkhani et al., *supra*.

[84] Nat'l Acads. of Scis., Eng'g, & Med. (hereinafter "NASEM"), *Effects of Human-Caused Greenhouse Gas Emissions on U.S. Climate, Health, and Welfare* (2025), https://doi.org/10.17226/29239.

[85] Smith, *supra*.

people (Fig. 5).[86] As of the end of September 2026, 21 billion-dollar disasters have led to 201 deaths and 50.3 billion USD in damages in 2026.[87] The rising costs of disasters are a consequence of growing climate risks as well as an increase in population and development in exposed areas such as coastal and inland floodplains and wildfire-prone geographies.

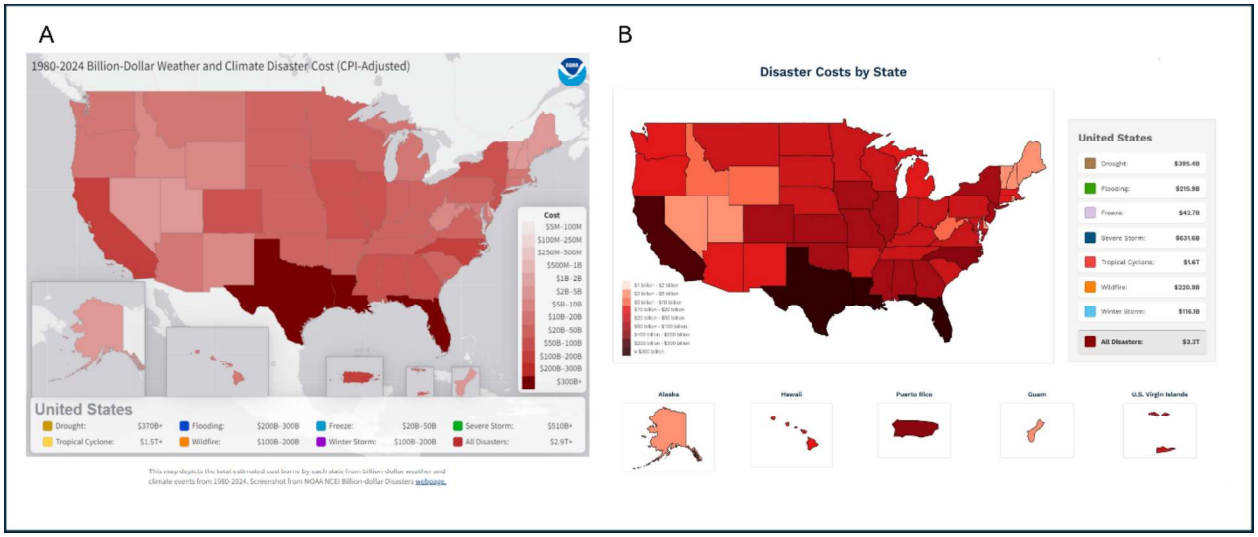



**Figure 5 -** Map of total costs from billion-dollar weather and climate disasters across the United States from A) 1980 to 2024 and B) 1980-2026 (both CPI-adjusted). Darker shading indicates higher total damages, with the greatest costs concentrated in Gulf Coast and southeastern states.[88, 89]

### Non-Linear Impacts from Warming Oceans

The ocean has absorbed about 91% of the excess heat trapped in the earth's atmosphere, primarily from burning fossil fuels, helping to limit the climate-change driven-temperature increase on land thus far.[90] However, the average temperature of the oceans is now rising

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[86] Smith, *supra*.

[87] Climate Central, *Disaster Mapping* (2026), https://www.climatecentral.org/climate-services/billion-dollar-disasters/mapping?years=2026-2026.

[88] Smith, *supra*.

[89] Climate Central, *Disaster Mapping* (2026), https://www.climatecentral.org/climate-services/billion-dollar-disasters/mapping?years=2026-2026.

[90] Nat'l Oceanic & Atmospheric Admin., *Ocean Heat*, https://globalocean.noaa.gov/the-ocean/ocean-heat/ (last visited Oct. 26, 2026).

steadily, and acute marine heatwaves are also increasing.[91,92,93] GMST and GSLR fail to consider the non-linear and profound impacts that these warmer ocean temperatures are having on regional extreme weather events, sea-level rise, and marine ecosystems in the United States. Warmer ocean temperatures provide more energy for hurricanes, leading to stronger, wetter, and in some cases slower-moving hurricanes, which can increase local damage from a single storm.[94,95] Extreme marine heatwaves are having consequential impacts to coastal ecosystems, including the stress and collapse of coral reefs in Florida,[96] Hawaii,[97] and the U.S. Virgin Islands,[98] and degradation of marine wildlife in Alaska,[99] the Gulf of Maine,[100] and the Pacific

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[91] Yuying Pan et al., *Ocean Heat Content Sets Another Record in 2025*, 43 Adv. Atmospheric Sci. 2019 (2026), https://doi.org/10.1007/s00376-026-5876-0.

[92] Joseph Giguere, Daniel M. Gilford & Andrew J. Pershing, *Attributing daily ocean temperatures to anthropogenic climate change*, 3 Env't Res.: Climate 035003 (2024), https://doi.org/10.1088/2752-5295/ad4815.

[93] Climate Central, *Climate Shift Index: Ocean*, https://csi.climatecentral.org/ocean.

[94] James P. Kossin, *A Global Slowdown of Tropical-Cyclone Translation Speed*, 558 Nature 104 (2018), https://doi.org/10.1038/s41586-018-0158-3.

[95] Daniel M. Gilford, Joseph Giguere & Andrew J. Pershing, *Human-Caused Ocean Warming Has Intensified Recent Hurricanes*, 3 Env't Rsch.: Climate 045019 (2024), https://doi.org/10.1088/2752-5295/ad8d02.

[96] Derek P. Manzello et al., *Heat-driven functional extinction of Caribbean Acropora corals from Florida's Coral Reef*, 390 Science 361 (2025), https://doi.org/10.1126/science.adx7825.

[97] Jason M. Gove et al., *Coral reefs benefit from reduced land–sea impacts under ocean warming*, 621 Nature 536 (2023), https://doi.org/10.1038/s41586-023-06394-w.

[98] Emilia C. Dell'Antonio, Lauren Mahoney & Peter J. Edmunds, *Marine heatwave decimates fire coral populations in the Caribbean*, 122 Proc. Nat'l Acad. of Scis. e2518506122 (2025), https://doi.org/10.1073/pnas.2518506122.

[99] Maya C. Rallu De Malibran, Chloe M. Kaplan & Emanuele Di Lorenzo, *Marine heatwaves suppress ocean circulation and large vortices in the Gulf of Alaska*, 5 Commu'ns Earth Env't 622 (2024), https://doi.org/10.1038/s43247-024-01785-x.

[100] Easton R. White et al., *Temperature extremes in the Gulf of Maine: A synthesis of marine heatwaves, cold-spells, and ecological impacts* (preprint 2026), https://doi.org/10.32942/X2TM3D.

Northwest.[101] Ocean warming also leads to thermal expansion, contributing to sea-level rise that can disproportionately cause frequent flooding across the Atlantic and Gulf Coast of the U.S.[102]

## V. Global Average Temperatures are the Wrong Metric for Health Impacts.

Similarly, a focus on GMST and GSLR fails to account for the inequitably distributed health harms that stem from climate change, including extreme heat, increases in exposure to wildfire smoke, and changes to vector-borne and water-borne diseases.[103,104] GMST and GSLR are spatially and temporally aggregated metrics that smooth over the regional and seasonal extremes and local variabilities where health impacts materialize. They reveal nothing about extreme events, differential exposure, vulnerability, or adaptive capacity—the factors that determine whether a temperature increase becomes a health crisis. An annual global average does not distinguish between an early season extreme heatwave or a community with air conditioning and green space versus one without; similarly, global sea level rise tells us little about which populations live near flood-prone hazardous sites. These metrics were designed to track planetary physics at an aggregated level, not human welfare, much less the welfare of Americans specifically.

GMST is the wrong indicator for health impacts because averages mask the reality of extreme heat and heatwaves or socioeconomic determinants of health, which are known to be major drivers of heat related deaths and illnesses globally and in the U.S. Climate change is already increasing the frequency, duration, and intensity of heatwaves, including increases in night-time heat.[105]

Failing to consider how increases in GMST manifest on the ground in the U.S. obscures the extent of the human health and welfare implications. Extreme heat days are also associated with

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[101] William W.L. Cheung & Thomas L. Frölicher, *Marine heatwaves exacerbate climate change impacts for fisheries in the northeast Pacific*, 10 Sci. Rep. 6678 (2020), https://doi.org/10.1038/s41598-020-63650-z.

[102] Sadaf Mahmoudi et al., *Escalating high tide flooding along the Atlantic and Gulf Coast of the United States due to sea level rise*, 13 Earth's Future e2024EF005328 (2025), https://doi.org/10.1029/2024EF005328.

[103] Ctrs. for Disease Control, *About CDC's Climate and Health Program* (Feb. 9, 2024), https://www.cdc.gov/climate-health/php/about/index.html.

[104] NASEM, *supra*.

[105] Marvel et al., *supra.*

a significant increase in emergency room visits.[106,107,108] Research also shows that climate-driven extreme heat could lead to a loss of about 1.2% in U.S. GDP per degree Celsius increase in temperature, including labor costs, mortality costs, and costs to major economic sectors.[109] Outdoor workers could experience an estimated $49.2 billion in annual earnings at risk by the end of the century.[110] Without action to curtail heat-trapping emissions, the incidence of extreme heat—and its impacts on people—will increase significantly in the U.S.[111] A focus solely on GMST fails to capture human health harms for Americans.

Extreme heat is the leading weather-related killer in the United States.[112] Driven by climate change, extreme heat and drought are becoming hotter, longer lasting, and more frequent.[113] The summer of 2024 was the hottest year on record for the world, however the global mean temperature reflected in that record does not capture the cascade of impacts that directly result from warmer temperatures globally and in the U.S. The long-term trend in the increase in frequency and intensity of heatwaves is a major challenge to human health, through heat exhaustion and heat stroke, and by exacerbating cardiovascular, respiratory, and kidney

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[106] Shengzhi Sun et al., *Ambient Heat and Risks of Emergency Department Visits among Adults in the United States: Time Stratified Case Crossover Study*, 375 BMJ e065653 (2021), https://doi.org/10.1136/bmj-2021-065653.

[107] Michelle Young, Kristina A. Dahl & Shubhayu Saha, *Climate change increases emergency department visits for heat-related illness in the United States*, 179 Climatic Change 1 (2026), https://doi.org/10.1007/s10584-026-04247-9.

[108] Hyojung Jang et al., *Identifying heat-related diagnoses in emergency department visits among adults in Chicago: A heat-wide association study*, 12 Sci. Advances eaed3977 (2026),https://doi.org/10.1126/sciadv.aed3977 https://www.science.org/doi/10.1126/sciadv.aed3977.

[109] Solomon Hsiang et al., *Estimating Economic Damage from Climate Change in the United States*, 356 Science 1362 (2017), https://doi.org/10.1126/science.aal4369.

[110] Rachel Licker, Kristina Dahl & John T. Abatzoglou, *Quantifying the Impact of Future Extreme Heat on the Outdoor Work Sector in the United States*, 10 Elementa: Sci. Anthropocene 48 (2022), https://doi.org/10.1525/elementa.2021.00048.

[111] Kristina Dahl et al., *Increased Frequency of and Population Exposure to Extreme Heat Index Days in the United States during the 21st Century*, 1 Env't Rsch. Commc'ns 07002 (2019), https://doi.org/10.1088/2515-7620/ab27cf.

[112] NOAA Nat'l Weather Serv., *Severe Weather Awareness - Heat Waves*, https://www.weather.gov/mkx/heatwaves (last visited Oct. 26, 2026).

[113] Drew Shindell et al., *The Effects of Heat Exposure on Human Mortality Throughout the United States*, 4 GeoHealth e2019GH000234 (2020), https://doi.org/10.1029/2019GH000234.

conditions.[114,115,116] Outdoor workers, elderly people, young children, pregnant people, people who are unhoused, and people with pre-existing health conditions are most at risk.[117,118] The impacts of climate change compound and build on each other. Heatwaves, for example, exacerbate cardiovascular and respiratory conditions,[119,120] while compromised food and water security[121] due to extreme heat and drought increases risks of malnutrition and infectious diseases.[122] Drought also contributes to respiratory and cardiovascular-related health impacts—dry conditions increase airborne dust and particulate matter while simultaneously elevating wildfire risk, exposing populations to fine particles that penetrate deep into lungs and trigger systemic inflammation.[123,124] Wildfire smoke has contributed to increasing trends of average annual concentrations of $PM_{2.5}$ in the contiguous United States since 2016, with the most

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[114] Marino et al., *supra.*

[115] NASEM, *supra.*

[116] Mary H. Hayden et al., *Human Health, in Fifth National Climate Assessment* ch. 15 (Allison R. Crimmins et al., eds., U.S. Global Change Rsch. Prog., 2023), https://doi.org/10.7930/NCA5.2023.CH15.

[117] Marina Romanello et al., *The 2024 Report of the Lancet Countdown on Health and Climate Change: Facing Record-Breaking Threats from Delayed Action*, 404 The Lancet 1847 (2024), https://doi.org/10.1016/S0140-6736(24)01822-1.

[118] Matthew Francis Chersich et al., *Associations between High Temperatures in Pregnancy and Risk of Preterm Birth, Low Birth Weight, and Stillbirths: Systematic Review and Meta-Analysis*, 371 BMJ m3811 (2020), https://doi.org/10.1136/bmj.m3811.

[119] Ismael H. Silveira et al., *Effects of Heat Waves on Cardiovascular and Respiratory Mortality in Rio de Janeiro, Brazil*, 18 PLOS ONE e0283899 (2023), https://doi.org/10.1371/journal.pone.0283899.

[120] Kyriaki Psistaki et al., *Heatwave Characteristics and Health Impacts: A Review of Epidemiological Evidence and Implications for Heatwave Response Plans*, 3 Env't Rsch.: Health 042003 (2025), https://doi.org/10.1088/2752-5309/ae1861.

[121] Sarah Lawrence, *Infectious Disease and Climate Change: Food & Water Scarcity*, Am. Security Project (Nov. 22, 2021), https://www.americansecurityproject.org/infectious-disease-and-climate-change-food-water-scarcity/.

[122] Romanello et al., *supra.*

[123] Yeongjin Gwon et al., *The Association between Drought Exposure and Respiratory-Related Mortality in the United States from 2000 to 2018*, 20 Int'l J. Env't Rsch. & Public Health 6076 (2023), https://doi.org/10.3390/ijerph20126076.

[124] Yeongjin Gwon et al., *The Effect of Heterogeneous Severe Drought on All-Cause and Cardiovascular Mortality in the Northern Rockies and Plains of the United States*, 912 Sci. Total Env't 169033 (2024), https://doi.org/10.1016/j.scitotenv.2023.169033.

pronounced impacts in western states.[125] Of roughly 164,000 wildfire-smoke deaths from 2006 to 2020, approximately 15,000 were attributable to climate change.[126]

A 2025 Commonwealth Fund report on climate and health highlighted that environmental hazards, many of which are exacerbated by climate change, are responsible for approximately 19% of deaths globally.[127] According to the 2025 Lancet Countdown report on Health and Climate Change, "*on average, 16 (84%) of the 19 life-threatening heatwave days that people were exposed to annually in 2020–24 would not have occurred without climate change."*[128] In the U.S., the health care sector itself is vulnerable: nearly 15% of hospital beds in Florida are in high-hazard flood zones, and facilities across the country are ill-prepared for the increasing frequency of extreme weather.[129] The report found that states with higher environmental risks and weaker clean energy policies face greater health burdens.

The impacts of climate change are not borne equally. Scientific evidence overwhelmingly shows that marginalized communities—low-income populations, communities of color, and Indigenous groups—face disproportionate risks[130] from both sea-level rise[131] and extreme weather, a reality not captured by a focus on global average temperature and global mean sea level rise.

A *Nature Communications* study on sea-level rise and hazardous sites revealed a stark environmental justice crisis. Controlling for population density, neighborhoods with higher proportions of renters, non-voters, linguistically isolated households, and residents living in poverty are significantly more likely to be located near hazardous sites at risk of flooding. They

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[125] Marshall Burke et al., *The Contribution of Wildfire to PM2.5 Trends in the USA*, 622 Nature 761 (2023), https://doi.org/10.1038/s41586-023-06522-6.

[126] Beverly E. Law et al., *Anthropogenic Climate Change Contributes to Wildfire Particulate Matter and Related Mortality in the United States*, 6 Commc'ns Earth & Env't 336 (2025), https://doi.org/10.1038/s43247-025-02314-0.

[127] Marino et al., *supra.*

[128] Marina Romanello et al., *The 2025 Report of the Lancet Countdown on Health and Climate Change: Climate Change Action Offers a Lifeline*, 406 The Lancet 2804 (2025), https://doi.org/10.1016/S0140-6736(25)01919-1.

[129] Marino et al., *supra.*

[130] EPA, Press Release, *EPA Report Shows Disproportionate Impacts of Climate Change on Socially Vulnerable Populations in the United States* (Sept. 2, 2021), https://www.epa.gov/newsreleases/epa-report-shows-disproportionate-impacts-climate-change-socially-vulnerable.

[131] Lara J. Cushing et al., *Sea Level Rise and Flooding of Hazardous Sites in Marginalized Communities across the United States*, 16 Nature Commc'ns 9711 (2025), https://doi.org/10.1038/s41467-025-65168-2.

found that a one standard deviation increase in the proportion of renters is associated with an up to 41% higher likelihood of having a hazardous site within 1 kilometer.[132]

This inequity is the result of historical land-use decisions and systemic discrimination. When sea levels rise or floods occur, these communities are the first to suffer contaminant releases, displacement, and health impacts. The cumulative impact of all of these factors exacerbates the disproportionate adverse health and welfare impacts for these communities, which EPA has completely failed to account for.

The Commonwealth Fund scorecard further illustrates this inequity. States with higher environmental risks often have weaker health care infrastructure and fewer resources for adaptation.[133] For example, low-lying coastal states like Florida and Louisiana have a high percentage of health care facilities in flood zones.

A focus on GMST and GSLR fails to capture both the human health impacts of climate change and the unequal effects of these impacts across populations and communities. As such, this focus is insufficient for preparing for the risks associated with current and further climate change in the U.S.

## VI. Summary

The characterization of climate change impacts based solely on global mean surface temperature and global mean sea level oversimplifies the complex challenges that arise from physical, societal, economic, and ecological impacts associated with these increases. While the global averages may appear "small" in isolation, they mask a reality of profound regional disparity and escalating risk. The U.S. East and Gulf Coasts are facing accelerated sea-level rise that inundates communities and threatens to flood hazardous sites within decades, not centuries. Alaska is warming at a rate that is destabilizing the very ground its communities stand on. Such regional differences highlight how GMST and GSLR alone are inadequate measures of the full impact of climate change on communities, ecosystems, and economies across the United States. And across the nation, extreme weather events, supercharged by climate warming, are inflicting billions of dollars in damage and causing significant threats to public health, including loss of life.

Here we show how frameworks that rely on global averages to assess risk at regional and local levels can systematically underestimate the threat to American health and welfare. For many Americans, the climate crisis is not a distant future scenario defined by global averages, but a present-day emergency defined by rising waters, intensifying storms, and disproportionate harm to the most vulnerable.

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[132] Cushing et al., *supra.*

[133] Marino et al., *supra.*