

# Global Warming on the Earth's Surface

Dilkush Sharma

**Abstract - Global warming is rapidly reshaping the Earth's surface, leading to unprecedented environmental changes. Recent records from 2024–2025 confirm that rising temperatures, melting ice, changing precipitation patterns, and increased frequency of extreme weather events are intensifying across regions. This paper synthesizes the latest scientific assessments, analyzes trends in land, ocean, and atmospheric systems, and evaluates socioeconomic and ecological impacts. Observed phenomena include global surface temperature anomalies exceeding historical records, substantial ice loss in Greenland and Antarctica, accelerated desertification, and shifting biomes. The study further explores the underlying anthropogenic and natural contributors to warming, focusing on fossil fuel emissions, land-use changes, and urbanization. Drawing from recent key indicators, the research discusses adaptation and mitigation strategies, outlines urgent challenges, and highlights opportunities for further research. The findings underscore the critical need for coordinated global action to maintain planetary health and safeguard human livelihoods in the face of rapid warming.**

**Keywords: Global warming, Earth's surface, climate change, surface temperature, ice loss, land-use change, fossil fuels, extreme weather, mitigation, adaptation, planetary health**

## I. INTRODUCTION

Global warming is defined as the long-term rise in Earth's average surface temperature, largely driven by increased concentrations of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Over the last century, surface warming has intensified, impacting diverse physical, biological, and socioeconomic systems. Current indicators demonstrate that the period from 2015 to 2024 represents the hottest decade on record, with surface temperature anomalies surpassing 1.54°C above historical averages by mid-2025. This paper investigates the most up-to-date evidence, mechanisms, consequences, and responses related to global warming's effects on the Earth's surface.

## II. PHYSICAL CHANGES ON THE EARTH'S SURFACE

### 1. Rising Global Surface Temperatures

The average surface temperature of the Earth has increased by approximately 2°F (1°C) since the late 19th century. This rise has accelerated in the past 15 years, with warming occurring at twice the rate observed in the previous 40 years. Temperature anomalies in 2025 reached unprecedented highs, including January values of 1.75°C above pre-industrial averages. These changes have not been uniform; polar regions, especially the Arctic, experience warming at rates far exceeding the global mean, with example events showing temperature deviations of up to 54°F above normal.

### 2. Land Surface Changes

Thirty percent of Earth's land area is largely unusable due to glaciers and deserts, while agriculture and forested areas dominate the remainder. Land-use change, especially deforestation for agriculture, releases vast amounts of carbon dioxide, limits carbon sequestration, and alters local albedo, which in turn affects surface warming. Between 2001–2018, 27% of deforestation was permanent, driven by agricultural expansion, while forestry practices and wildfires contributed to almost half of global tree cover loss.

## III. OCEAN SURFACE AND CRYOSPHERE

Oceans have absorbed 90% of excess heat, with warming most pronounced in the upper 100 meters. This has caused changes in ocean currents, reduced oxygen levels, and more intense marine heatwaves. Since 1993, Greenland and Antarctic ice sheets have shrunk by thousands of gigatonnes, fueling sea level rise and ecological disruption. Minimum sea ice levels reached fresh record lows, threatening polar habitats and coastal stability.

### 1.3 Drivers and Mechanisms

#### 1. Greenhouse Gas Emissions

Anthropogenic emissions continue to drive warming trends. In 2025, carbon dioxide concentrations surpassed 430 ppm at Mauna Loa, Hawaii—levels unseen in millions of years. Fossil fuel consumption remains dominant, with coal, oil, and natural gas usage peaking and energy-related emissions hitting 40.8 gigatonnes of CO<sub>2</sub> equivalent in 2024. Methane and nitrous oxide emissions have also reached record high concentrations, intensifying radiative forcing.

#### 2. Land-Use Change and Albedo Effects

Changes in surface vegetation alter albedo—the measure of solar reflectivity—which influences local and global temperature. Replacement of forests with agriculture or urban areas generally raises local temperatures by reducing evaporation and altering cloud formation. In high latitudes, ice or snow-covered surfaces reflect more sunlight, sometimes causing localized cooling effects when forests are removed.

#### 3. Urbanization and Industrialization

Urban areas amplify warming due to the 'urban heat island' effect, leading to elevated temperatures compared to surrounding rural zones. Rapid urban development and industrial growth have contributed to increased energy demand, further driving fossil fuel combustion and associated emissions.

# Global Warming on the Earth's Surface

## IV. IMPACTS AND CONSEQUENCES

### 1. Extreme Weather Events

Global warming is linked to an uptick in extreme weather frequency and severity. Heat waves, record-breaking wildfires, hurricanes, and droughts are increasingly common, each causing considerable damage to infrastructure, human health, and ecological resilience. The number of days exceeding the 90th percentile baseline for temperature now represent record highs[], and marine heatwaves are disrupting global fisheries and coral reef systems.

### 2. Ice Loss and Sea Level Rise

Melting glaciers, ice sheets, and sea ice contribute directly to rising sea levels. Greenland and West Antarctic ice sheets are approaching critical tipping points, suggesting the planet may be committed to meters of sea level rise in future decades. Coastal flooding and erosion have become regular, threatening densely populated low-lying regions.

### 3. Biodiversity and Ecosystem Shifts

Species loss, habitat fragmentation, and biome shifts have accelerated, impacting global biodiversity. Coral reefs suffered unprecedented bleaching in 2024–2025, with over 84% affected. Shifts in precipitation patterns and temperature regimes have altered crop viability, threatened food security, and reorganized ecosystem functions.

### 4. Socioeconomic Effects

Climate change impacts agriculture productivity, water availability, health outcomes, and economic stability. Increases in drought, shifting monsoon patterns, and heat stress endanger crops and livestock, while more frequent disasters elevate humanitarian and socioeconomic costs.

## V. ADAPTATION AND MITIGATION STRATEGIES

### 1. Renewable Energy and Emissions Reductions

Worldwide, renewable energy infrastructure is expanding. Though solar and wind use grew by 16.4% in 2024, fossil fuel consumption is still 31 times higher. The need for aggressive decarbonization strategies is clear, as top emitters (China, US, India, EU, Russia) account for two-thirds of emissions. Larger investments in energy efficiency, carbon capture, and behavioral change are required.

### 2. Land Management and Restoration

Deforestation and unsustainable land practices remain critical challenges. Programs for forest restoration, improved agricultural practices, and ecosystem-based adaptation have shown promise in enhancing carbon sinks, biodiversity, and climate resilience.

### 3. International Policy and Agreements

Global initiatives, including COP summits and IPCC assessments, aim to limit warming below critical thresholds

(1.5°C–2°C). However, progress is inconsistent due to economic, political, and logistical hurdles. Urgent action is required to meet sustainable development and climate targets.

## VI. CHALLENGES AND UNCERTAINTIES

### 1. Critical Tipping Points

Several physical systems are nearing or have crossed thresholds beyond which change may become irreversible—these include ice sheet collapse, coral bleaching, and permafrost thawing. The consequences of passing these tipping points range from multi-meter sea level rise to widespread ecological transformation.

### 2. Climate Modeling and Attribution

Uncertainties persist in modeling regional impacts and attributing causality, especially regarding feedback mechanisms such as cloud cover, ocean heat uptake, and terrestrial carbon cycling. Continued investment in climate science, observation, and cross-disciplinary collaboration is essential.

## VII. DIRECTIONS FOR FUTURE RESEARCH

### 1. Monitoring and Assessment

Ongoing satellite and ground-based observations are vital for tracking surface changes, temperature anomalies, and biogeochemical processes. Improved climate models with higher spatial resolution and treatment of nonlinear feedbacks are needed.

### 2. Innovations in Adaptation

Research into climate-resilient crops, water management, urban planning, and natural disaster response can minimize vulnerability. Socioeconomic studies should further examine the role of governance, equity, and technology in adaptation success.

### 3. Climate Communication and Education

Raising public awareness, fostering community engagement, and integrating climate education into curricula are fundamental for driving change at all societal levels.

## VIII. CONCLUSION

As of 2025, global warming has fundamentally altered the Earth's surface, producing record-breaking temperature anomalies, catastrophic ice loss, extreme weather events, and far-reaching consequences for human societies and natural systems. Fossil fuel emissions, deforestation, and urbanization continue to drive rapid change. While advances in renewable energy, land management, and policy have made progress, these efforts pale against the scale of current disruptions. Achieving planetary health and resilience requires a redoubling of mitigation and adaptation initiatives, strengthened international collaboration, and support for innovation and education. Failure to act risks

destabilizing the Earth's surface and the life it supports for generations to come.

#### REFERENCES

- [1] NASA. "The Effects of Climate Change." 2024.
- [2] Down to Earth. "Climate Crisis Alert: 22 of 34 Key Indicators Hit Record Highs." 2025.
- [3] Copernicus Climate Change Service. "State of the Climate Reports." 2024.
- [4] IPCC. "Climate Change Widespread, Rapid, and Intensifying." 2021.
- [5] United Nations. "Causes and Effects of Climate Change." 2021.
- [6] Wikipedia. "Climate Change – Land Surface Changes." 2025.
- [7] Earth.org. "15 Biggest Environmental Problems of 2025." 2025.
- [8] EPA. "Causes of Climate Change." 2025.
- [9] IPCC. "Special Report: Global Warming of 1.5 °C." 2012.
- [10] Protect Earth Foundation. "Explore the Surprising Global Warming Effects" 2025.

**Dilkush Sharma**, Assistant Professor, Department of Geography,  
Sardhanath PG College Gudha Godji, (Jhunjhunu)