Climate Change – Causes and Consequences

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Climate Change

Weather: Short-term atmospheric conditions, including temperature, precipitation, and wind, occurring locally.

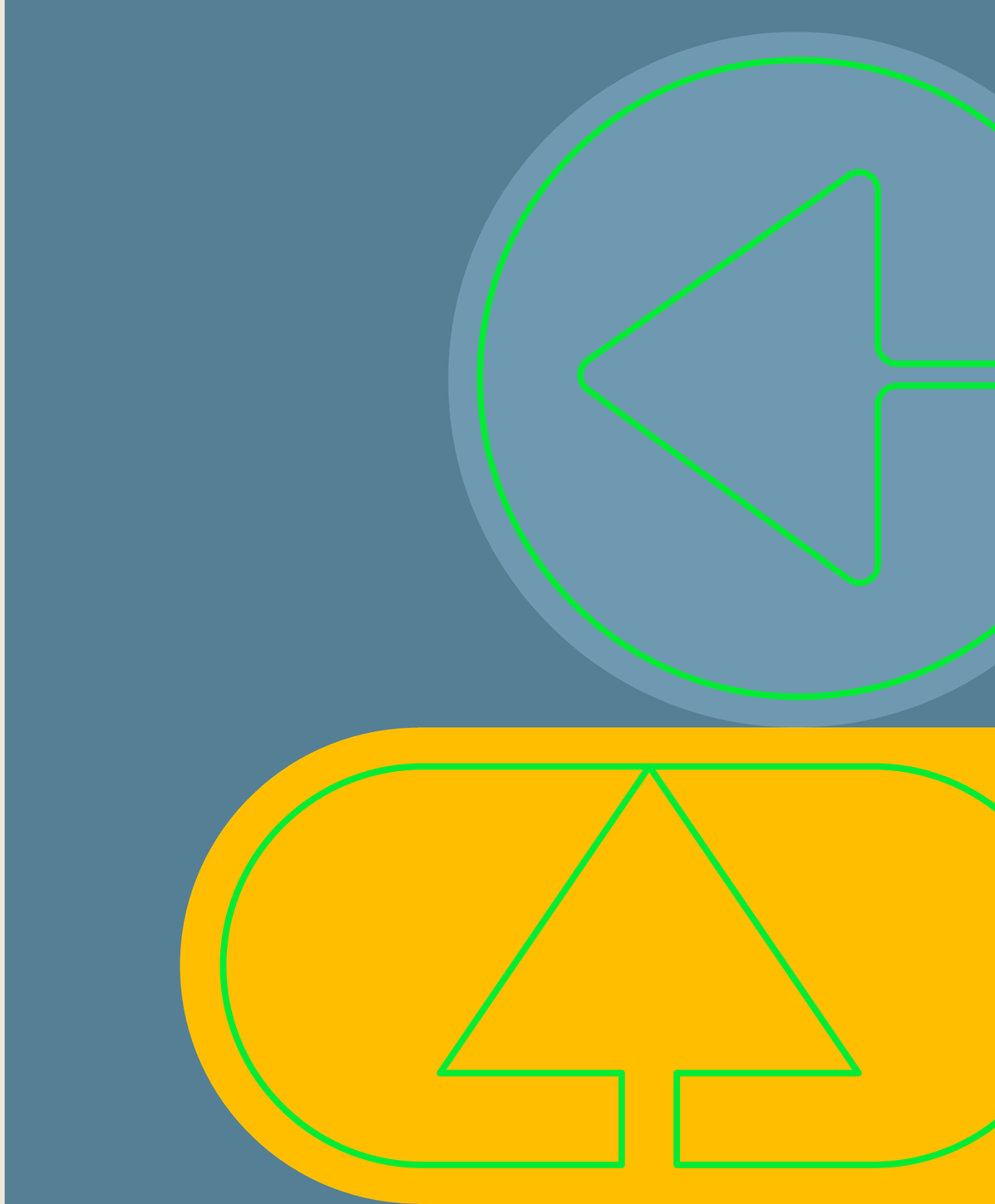
Climate: Long-term average of weather patterns in a specific region or globally, typically assessed over 30 years or more.

Weather vs. Climate: Weather refers to short-term, local conditions, while climate describes long-term averages and patterns.

Climate Change: Requires sustained observation and rigorous statistical analysis over a long period, typically 30 years.

Natural Climate Variability: Occurs on various timescales due to factors like ocean patterns and volcanic eruptions.

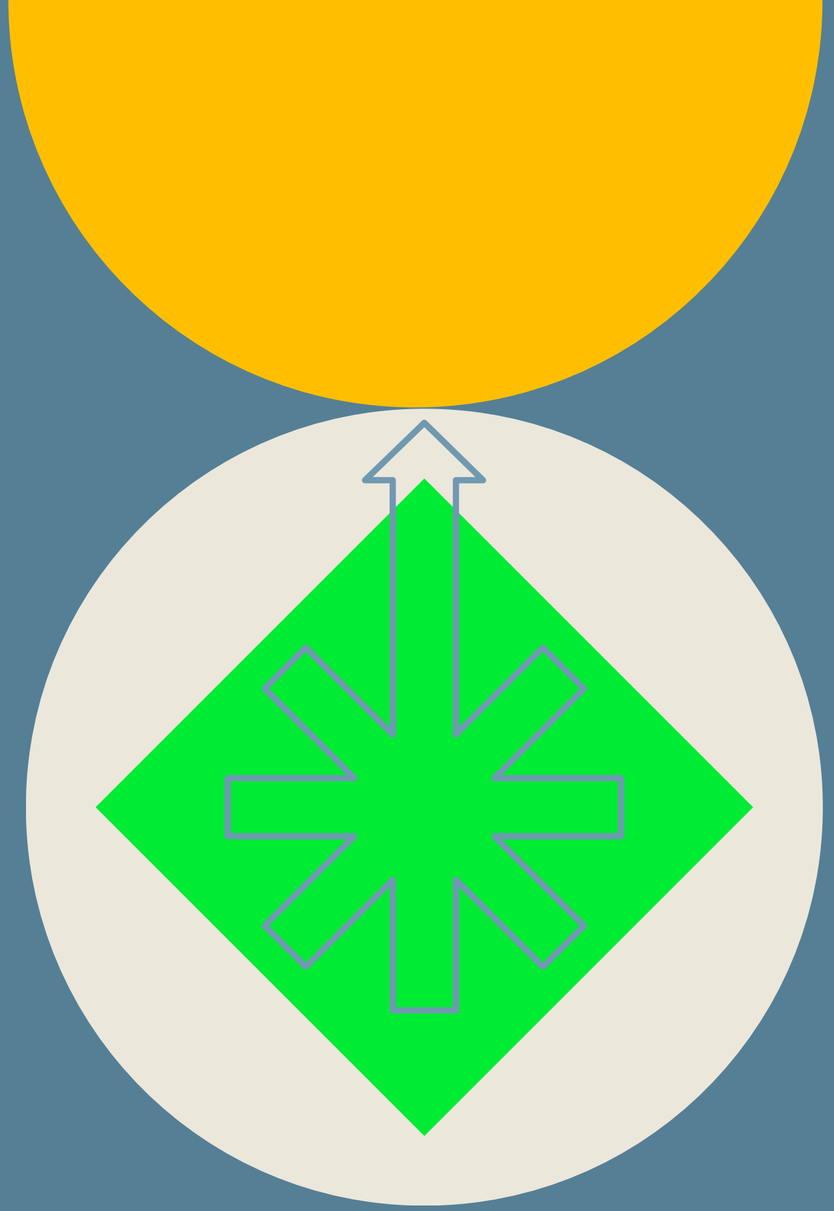
Climate Change Detection: A statistically significant trend relative to background variability over the long term.



The Reality of Change: Long-Term Trends and Pace

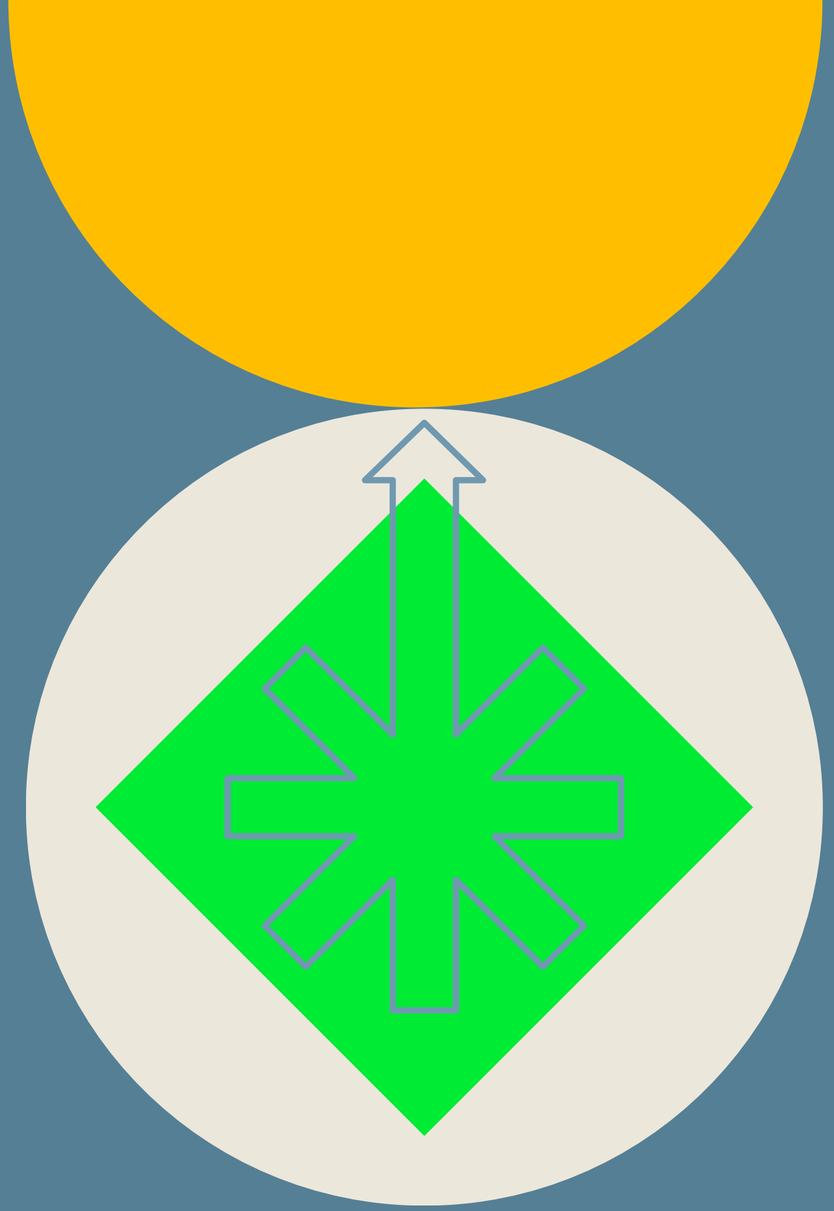
- Scientific evidence confirms that Earth’s climate system is changing.
- The changes are occurring rapidly compared to the pace of natural climate variations.
- The current rate of warming is roughly ten times faster than the average rate of warming after past ice ages.
- The increase in atmospheric carbon dioxide resulting from human activities is occurring about 250 times faster than it did from natural sources following the last Ice Age.
- The rapid pace of change limits the time available for natural adjustments and human societies to adapt.
- The rate of change is as critical a factor as the overall magnitude of change itself.





The Engine of Warming: The Greenhouse Effect and Human Influence

- The natural greenhouse effect is a process vital for life on Earth.
- It begins with energy from the Sun reaching Earth's atmosphere.
- Some solar energy is reflected back to space, while about half passes through the air and clouds to the surface.
- The warmed Earth then radiates energy back towards space in the form of infrared heat.
- Greenhouse gases (GHGs) naturally present in the atmosphere intercept much of this outgoing infrared radiation.
- These gases include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
- They absorb the heat and re-radiate it in all directions, including back towards the Earth's surface.
- This trapping of heat slows its loss to space, effectively acting like a blanket and warming the planet.
- The natural greenhouse effect maintains Earth's average surface temperature at around 15°C (59°F).
- Without the natural greenhouse effect, Earth's surface would be well below freezing, averaging about -18°C (-1°F).
- Water vapor is the most abundant greenhouse gas and plays a significant role, but its concentration in the atmosphere is primarily controlled by temperature.



The Engine of Warming: The Greenhouse Effect and Human Influence

- Carbon dioxide, although less abundant than water vapor, plays a crucial role in maintaining the stability of the atmosphere and the overall greenhouse effect.
- The analogy of a “greenhouse” is not physically accurate.
- A horticultural greenhouse works by restricting air movement, preventing warm air from rising and escaping.
- The atmospheric greenhouse effect operates through a radiative process: specific gas molecules absorbing and re-emitting infrared radiation.
- The natural greenhouse effect demonstrates Earth’s climate sensitivity to its atmospheric composition.
- Naturally occurring trace gases maintain a temperature difference of approximately 33°C.
- Artificially increasing the concentrations of these heat-trapping gases must inevitably lead to an enhancement of this warming effect.

The Engine of Warming: The Greenhouse Effect and Human Influence



- The natural greenhouse effect is essential for Earth’s energy balance.
- Human activities since the Industrial Revolution have significantly altered Earth’s energy balance.
- The burning of fossil fuels, deforestation, agricultural practices, and industrial processes have released vast quantities of greenhouse gases into the atmosphere.
- This surge in anthropogenic GHG emissions has led to substantially higher concentrations of these gases compared to pre-industrial levels.
- The increase in atmospheric GHGs intensifies the natural greenhouse effect.
- More greenhouse gas molecules present absorb and re-radiate back down a larger fraction of the infrared heat radiated from Earth’s surface, trapping additional heat and causing the planet’s average temperature to rise.
- The human-caused amplification of the greenhouse effect is often referred to as the “enhanced” greenhouse effect.

The Engine of Warming: The Greenhouse Effect and Human Influence



- The enhanced effect does not involve a different type of physical mechanism; rather, it is an intensification of the same natural radiative trapping process, driven by higher concentrations of the relevant gases.
- The scientific consensus is that human influence on the climate system is unequivocal and is the primary driver of the observed warming since the mid-20th century.
- The Industrial Revolution serves as a critical historical benchmark because it marks the beginning of large-scale reliance on fossil fuels and the associated dramatic increase in GHG emissions.
- Atmospheric concentrations of key GHGs, particularly CO2, have since risen to levels unprecedented not only in human history but also over hundreds of thousands of years, as revealed by paleoclimate data from ice cores.
- This historical context starkly highlights the anomalous nature and scale of the recent, rapid changes driven by industrialization and other human activities.

Key Greenhouse Gases: Sources, Properties, and Contributions

Gas Name	Chemical Formula	Primary Anthropogenic Sources	Approx. Atmospheric Lifetime	100-year GWP (relative to CO2=1)	Pre-industrial Conc. (approx.)	2023 Conc. (approx.)
Carbon Dioxide	CO2	Fossil fuel combustion, deforestation, cement production, land use change	Variable (50-200+ years)	1	~280 ppm	~421 ppm 8
Methane	CH4	Agriculture (livestock, rice), fossil fuel extraction/transport, landfills	~12 years	28-34	~722 ppb	~1900+ ppb
Nitrous Oxide	N2O	Agriculture (fertilizers, soil management), industry, fossil fuel combustion	~114 years	265-298	~270 ppb	~335+ ppb
Hydrofluorocarbons (HFCs)	Various	Refrigerants, aerosols, solvents (replacements for CFCs/HCFCs)	Variable (years to centuries)	Variable (e.g., HFC-134a: ~1,430)	Near zero	Increasing
Perfluorocarbons (PFCs)	Various	Industrial processes (e.g., aluminum production, semiconductor manufacturing) 18	Thousands of years	Variable (e.g., CF4: ~7,390)	Near zero	Increasing
Sulfur Hexafluoride	SF6	Electrical transmission equipment, industrial processes 17	~3,200 years	~23,500	Near zero	Increasing

Radiative Forcing: Quantifying the Imbalance

- The concept of Radiative Forcing (RF) is used to compare the climate impacts of different factors.
- RF quantifies the change in Earth's energy balance at the top of the atmosphere caused by a specific climate driver.
- A positive RF indicates a warming effect, while a negative RF indicates a cooling effect.
- Human activities have substantially increased the atmospheric concentrations of well-mixed greenhouse gases (WMGHGs), leading to a strong positive RF.
- This positive forcing from GHGs is the primary driver of modern climate change.
- Some human activities, particularly the emission of aerosols, generally exert a negative RF.
- Aerosol cooling partially offsets the warming caused by GHGs, though the magnitude of aerosol forcing remains a significant source of uncertainty.
- The warming effect from human-added GHGs has significantly increased over recent decades.
- From 1990 to 2023, the total positive RF from GHGs added by humans increased by 51%.
- The warming effect associated with CO_2 alone increased by 42% over this same period.



Radiative Forcing: Quantifying the Imbalance

- The IPCC concluded that human activities, principally through GHG emissions, have unequivocally caused global warming.
- The concept of RF allows scientists to quantitatively assess and compare the contributions of various factors.
- By comparing the calculated RF from different drivers, it becomes clear that the positive forcing from anthropogenic GHGs far outweighs the forcing from natural factors.
- The existence of a significant negative forcing from aerosols carries an important implication.
- The global warming observed to date is likely less than what would have occurred from GHG emissions alone, because the aerosol cooling effect has been masking some of the warming.
- Efforts to improve air quality by reducing aerosol pollution could lead to an “unmasking” of additional warming.
- The rate of surface temperature increase could accelerate if GHG emissions are not simultaneously and drastically reduced.



Evidence for a Changing Planet: Observations and Data

- Rising Global Temperatures: Land and Ocean
- Shrinking Cryosphere: Glaciers, Ice Sheets, and Sea Ice
- Sea Level Rise: Acceleration
- Atmospheric Changes: Rising Greenhouse Gas Concentrations
- Extreme Weather Trends: Heatwaves, Precipitation, Storms

Indicator	Observed Change	Timeframe / Baseline
Global Avg. Surface Temperature	Increased by ~1.1°C (2°F)	Since 1850-1900
Global Mean Sea Level	Risen by ~21–24 cm (8–9 inches)	Since 1880
Atmospheric CO2 Concentration	Increased from ~280 ppm to >421 ppm (>50% increase)	Pre-industrial to 2023
Arctic Sea Ice Minimum Extent	Declining trend (~13% per decade relative to 1981-2010 average)	Satellite era (since 1979)
Glacier Mass Balance	Consistent negative balance (net ice loss) for >3 decades	World Glacier Monitoring Service data
Ocean Heat Content	Significant increase, absorbing >90% of excess heat	Since 1970s
Extreme Heat Events	Increased frequency and intensity in many regions	Observational records
Heavy Precipitation Events	Increased frequency and intensity over most land regions	Observational records

Attributing Change: Disentangling Human and Natural Factors

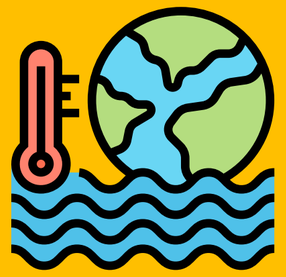
- The scientific consensus is that human influence has warmed the atmosphere, ocean, and land.
- The primary driver of this warming is the increase in atmospheric concentrations of greenhouse gases resulting from human activities.
- Climate models are essential tools for attribution and cannot reproduce the observed warming trend without including the increase in anthropogenic greenhouse gases.
- The specific patterns or "fingerprints" of observed climate change match those expected from GHG forcing.
- The observed warming pattern of the lower atmosphere (troposphere) while cooling the upper atmosphere (stratosphere) is consistent with GHG forcing.
- The detailed comparison of observed patterns with the patterns expected from different potential drivers strongly implicates greenhouse gases as the primary cause of the observed warming.
- The "fingerprinting" methodology moves beyond simple correlation to establish a causal link between human activities and climate change.

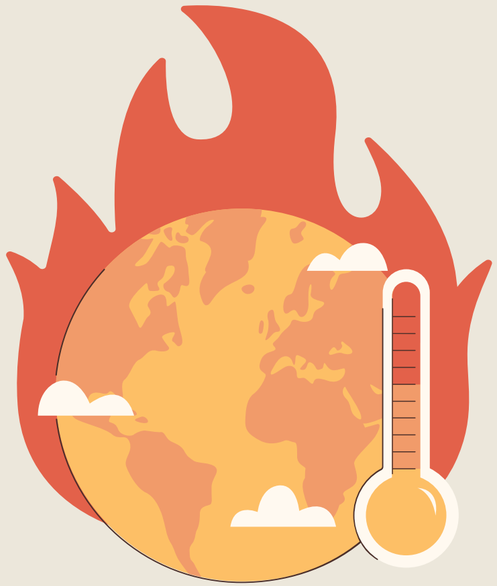


Evaluating Natural Factors: Solar Variability and Volcanic Activity

- Earth’s climate has naturally varied throughout its history due to factors unrelated to human activity.
- Key natural drivers include variations in the amount of energy received from the Sun and large volcanic eruptions.
- The Sun’s energy output fluctuates slightly, for example, following an approximately 11-year cycle.
- Major volcanic eruptions inject large amounts of sulfur dioxide gas into the stratosphere, where it forms sulfate aerosols that reflect sunlight and cause short-term global cooling.
- Over much longer timescales (tens to hundreds of thousands of years), subtle variations in Earth’s orbit around the Sun (Milankovitch cycles) have driven the cycles of ice ages and warmer interglacial periods.
- However, these known natural factors cannot explain the rapid warming observed since the mid-20th century.
- Direct satellite measurements show that there has been no net increasing trend in the Sun’s energy output over the past several decades that could account for the observed temperature rise.
- Volcanic eruptions cause temporary cooling, not sustained warming.







Consequences of a Warmer World: Observed and Projected Impacts

Ocean Impacts: Warming, Acidification, and Deoxygenation

- The oceans have absorbed the majority of excess heat from global warming.
- This ocean warming contributes to sea-level rise and intensifies marine heatwaves.
- The oceans also absorb a large fraction of excess CO2 emitted into the atmosphere.
- When CO2 dissolves in seawater, it forms carbonic acid, leading to ocean acidification.
- Ocean acidification poses a threat to many marine organisms, particularly those that build shells or skeletons from calcium carbonate.
- Increased acidity makes it harder for these organisms to form their protective structures and can cause existing shells to dissolve.
- Ocean acidification has potentially devastating consequences for entire ecosystems.
- Climate change can also lead to deoxygenation, a reduction in the amount of dissolved oxygen in parts of the ocean.
- Warmer water holds less dissolved gas, including oxygen, and changes in ocean circulation patterns can affect oxygen supply to deeper waters.
- Reduced oxygen levels create “hypoxic zones” that further stress marine life and can lead to habitat loss.





Consequences of a Warmer World: Observed and Projected Impacts

Ecosystem and Biodiversity Stresses

- Climate change is putting pressure on terrestrial and freshwater ecosystems, threatening biodiversity.
- Regional climates are shifting, causing plant and animal species to alter their geographic ranges.
- The pace of climate change may exceed the ability of some species to migrate, and barriers like habitat fragmentation can impede movement.
- Changes in temperature and precipitation patterns are altering habitats directly.
- The timing of key seasonal biological events is shifting in many ecosystems, leading to mismatches between species that depend on each other.
- Increased frequency and intensity of extreme events like droughts, wildfires, floods, and heatwaves cause direct mortality and habitat destruction.
- Coral reefs are particularly vulnerable, suffering from mass bleaching events caused by marine heatwaves and ocean acidification.
- Climate change often acts as a "threat multiplier," exacerbating existing pressures on biodiversity.
- The cumulative impact of these interacting stressors makes it increasingly difficult for species and ecosystems to cope and adapt, increasing the risk of species extinction.
- The IPCC has estimated that a substantial fraction of plant and animal species face a high risk of extinction this century if climate change continues at its current rate.





Consequences of a Warmer World: Observed and Projected Impacts

Impacts on Water Resources: Droughts and Floods

- Climate change is altering the global water cycle.
- This leads to significant impacts on water resources.
- Warming generally intensifies the water cycle.
- Wet regions become wetter, and dry regions become drier.
- This means an increased risk of more intense rainfall and associated flooding in some areas.
- Other regions face longer and more severe droughts.
- Changes in snowpack and melt patterns are critical in regions reliant on snowmelt for their water supply.
- Warmer temperatures lead to more precipitation falling as rain instead of snow.
- This reduces snow accumulation and earlier spring snowmelt.
- This alters the timing and availability of water downstream.
- This potentially leads to water shortages during drier summer months.
- These changes in precipitation patterns, drought frequency and severity, and snowmelt dynamics directly impact the availability and quality of water for drinking, agriculture, energy production, and ecosystems.
- Managing water resources effectively in the face of these intensifying hydrological extremes poses a major challenge for societies worldwide.





Consequences of a Warmer World: Observed and Projected Impacts

Human Health and Societal Vulnerabilities

- Climate change poses significant direct and indirect threats to human health and well-being.
- More frequent, intense, and longer-lasting heatwaves increase the risk of heat stress, heat exhaustion, and potentially fatal heatstroke.
- Extreme heat caused tens of thousands of deaths in Europe in 2022 alone.
- Climate change can also worsen air quality.
- Higher temperatures can increase the formation of ground-level ozone, a harmful pollutant that exacerbates respiratory illnesses like asthma.
- Increased frequency or severity of wildfires releases large amounts of particulate matter and toxic compounds into the air, posing significant respiratory risks over large areas.
- Changes in water availability and quality, including contamination following floods or concentration of pollutants during droughts, can increase the risk of waterborne diseases.
- Changes in temperature and precipitation patterns can also alter the geographic range and transmission season of vector-borne diseases.
- Extreme weather events like floods, storms, and droughts cause direct injuries, deaths, and displacement.





Consequences of a Warmer World: Observed and Projected Impacts

Human Health and Societal Vulnerabilities

- They can also damage healthcare facilities and disrupt access to essential services.
- The psychological toll of experiencing extreme events, losing homes or livelihoods, and facing uncertainty about the future can lead to significant mental health impacts.
- Changing temperatures, water availability, and extreme events can threaten food security in many regions.
- Climate-related disasters and gradual environmental degradation can force people to leave their homes, leading to internal displacement and cross-border migration.
- In 2022, natural disasters, many linked to climate change, resulted in millions of internal displacements.
- Vulnerable populations, including those in low-income communities, the elderly, children, Indigenous peoples, and communities reliant on climate-sensitive livelihoods, often face disproportionately higher exposure and risk.
- Climate justice and equity must be addressed in climate action to address the disparity in impacts.

Future Outlook and Projections

Climate Models and Scenarios

- Climate models are complex mathematical representations of the Earth's climate system.
- They are based on fundamental laws of physics and chemistry.
- They simulate interactions between the atmosphere, oceans, land surface, and ice.
- They allow scientists to explore how the climate responds to various forcings.
- These models are constantly being evaluated against historical climate data and improved.



Future Outlook and Projections

Climate Models and Scenarios

- They are run under different plausible scenarios of future socioeconomic development, technological advancement, and policy choices.
- These scenarios translate into varying pathways of future greenhouse gas emissions and land use.
- Common sets of scenarios include the Representative Concentration Pathways (RCPs) and the newer Shared Socioeconomic Pathways (SSPs).
- They provide valuable insights into potential future climate conditions and associated impacts under different emissions trajectories.



Future Outlook and Projections

Projected Future Changes Based on Emissions Pathways

- Climate model projections consistently indicate that global temperatures will continue to rise for at least the next few decades.
- The amount of warming expected by the end of the 21st century and beyond depends critically on the emissions pathway the world follows.
- Under scenarios with continued high greenhouse gas emissions, models project that global average surface temperature could rise by 5°F (2.8°C) to potentially more than 10°F (5.6°C) above pre-industrial levels by 2100.



Future Outlook and Projections

Projected Future Changes Based on Emissions Pathways

- Such levels of warming would lead to profound and potentially catastrophic changes across the planet.
- Scenarios involving rapid and deep reductions in global greenhouse gas emissions offer the possibility of limiting global warming to levels closer to the internationally agreed targets of well below 2°C, and preferably 1.5°C, above pre-industrial levels.
- Achieving these ambitious targets requires immediate, substantial, and sustained cuts in emissions across all sectors of the global economy.



Future Outlook and Projections

Projected Future Changes Based on Emissions Pathways

- Regardless of the specific emissions pathway, future climate change is projected to involve further increases in the frequency and intensity of extreme heat events, with cold extremes continuing to become less severe.
- Heavy precipitation events are projected to become more intense and frequent in most regions.
- Changes in drought patterns are expected to continue, with increases likely in some regions.



Future Outlook and Projections

Projected Future Changes Based on Emissions Pathways

- Sea levels are projected to continue rising throughout the 21st century and beyond, with the amount and rate of rise strongly dependent on future emissions and the response of ice sheets.
- Significant further impacts on ecosystems, water resources, human health, and infrastructure are anticipated.
- The severity of future climate change is not predetermined.
- The choices made today and in the coming years regarding energy systems, industrial practices, land management, and international cooperation will largely dictate the climate trajectory for the remainder of this century and beyond.



Future Outlook and Projections

Projected Future Changes Based on Emissions Pathways

- Even if global warming is successfully limited to 1.5°C or 2°C, significant further impacts compared to the present day are still expected.
- The changes and impacts already observed at around 1.1-1.2°C of warming demonstrate the sensitivity of natural and human systems.
- There is no truly “safe” level of climate change; rather, lower levels of warming correspond to progressively lower, but still substantial, risks and damages.
- Alongside ambitious mitigation efforts to reduce emissions, significant investment in adaptation measures to cope with the unavoidable impacts of climate change already locked into the system is essential.



Conclusion: Synthesis and Urgency

- The scientific evidence presented provides a clear and compelling picture of Earth’s changing climate.
- The distinction between short-term weather and long-term climate is fundamental.
- Climate change is defined as significant shifts in average conditions over decades or longer.
- Global warming, the long-term heating of Earth’s surface, is a primary component of this broader climate change.
- Overwhelming evidence from multiple independent sources confirms that the planet is warming at an unprecedented rate.
- This includes rising global air and ocean temperatures, widespread melting of glaciers and ice sheets, declining Arctic sea ice, rising sea levels, and increasing concentrations of greenhouse gases in the atmosphere.

Human-induced climate change is already affecting the frequency and intensity of many extreme weather events globally.





Conclusion: Synthesis and Urgency

- The scientific consensus, rigorously assessed by the IPCC, is unequivocal: human activities are the dominant cause of the observed warming since the mid-20th century.
- The primary driver is the emission of greenhouse gases – principally carbon dioxide, methane, and nitrous oxide – from burning fossil fuels, deforestation, agriculture, and industrial processes, which enhance the natural greenhouse effect.
- While natural factors like solar variability and volcanic eruptions influence climate, they cannot explain the rapid warming trend observed over the past century.
- The consequences of human-caused climate change are already widespread and profound.
- They impact oceans (warming, acidification), ecosystems (biodiversity loss, range shifts), water resources (droughts, floods), human health, coastal communities, and infrastructure.
- Future projections indicate that these impacts will intensify.





Conclusion: Synthesis and Urgency

- The severity of the impacts will depend on the pathway of future greenhouse gas emissions.
- High-emissions scenarios lead to potentially catastrophic outcomes.
- Rapid and deep emissions reductions offer a chance to limit warming and associated risks.
- Significant challenges remain even under lower warming targets.
- Addressing climate change represents one of the most critical challenges of the 21st century.
- It demands an urgent and coordinated global response.
- The response should encompass both mitigation (reducing greenhouse gas emissions) and adaptation (implementing measures to cope with impacts).
- Effectively tackling this issue requires an interdisciplinary approach.
- It should integrate insights from natural sciences, economics, social sciences, engineering, ethics, and policy.
- The scientific evidence is clear; the trajectory of future climate change rests heavily on the choices made today.





Thank You! Citations:

- What's the difference between climate and weather? - NOAA, accessed May 5, 2025, https://www.noaa.gov/explainers/what-s-difference-between-climate-and-weather
- What Is Climate Change? - NASA Science, accessed May 5, 2025, https://science.nasa.gov/climate-change/what-is-climate-change/
- What's the Difference Between Weather and Climate? | News | National Centers for Environmental Information (NCEI), accessed May 5, 2025, https://www.ncei.noaa.gov/news/weather-vs-climate
- Key Definitions and Literature Cited | NOAA Climate.gov, accessed May 5, 2025, https://www.climate.gov/teaching/climate/key-definitions-and-literature-cited
- climateknowledgeportal.worldbank.org, accessed May 5, 2025, https://climateknowledgeportal.worldbank.org/overview#:~:text=While%20the%20weather%20can%20change,over%20several%20decades%20or%20longer.
- Climate Change Overview, accessed May 5, 2025, https://climateknowledgeportal.worldbank.org/overview
- Energy and Climate Change, accessed May 5, 2025, https://understand-energy.stanford.edu/why-we-care/energy-and-climate-change
- Climate Change: Atmospheric Carbon Dioxide, accessed May 5, 2025, https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide
- Climate change impacts | National Oceanic and Atmospheric Administration, accessed May 5, 2025, https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts
- Evidence - NASA Science, accessed May 5, 2025, https://science.nasa.gov/climate-change/evidence/
- Global Warming - NASA Earth Observatory, accessed May 5, 2025, https://earthobservatory.nasa.gov/features/GlobalWarming
- What is the greenhouse effect? - NASA Science, accessed May 5, 2025, https://science.nasa.gov/climate-change/faq/what-is-the-greenhouse-effect/
- Causes of climate change | AdaptNSW - NSW Government, accessed May 5, 2025, https://www.climatechange.environment.nsw.gov.au/why-adapt/causes-climate-change
- The Causes of Climate Change - NASA Science, accessed May 5, 2025, https://science.nasa.gov/climate-change/causes/
- FAQ 1.3 What is the Greenhouse Effect? - IPCC, accessed May 5, 2025, https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html
- Understanding climate change - DCCEEW, accessed May 5, 2025, https://www.dcceew.gov.au/climate-change/policy/climate-science/understanding-climate-change
- The Science of Climate Change – Environmental Biology - University of Minnesota Libraries, accessed May 5, 2025, https://pressbooks.umn.edu/environmentalbiology/chapter/the-science-of-climate-change/
- Basics of Climate Change | US EPA, accessed May 5, 2025, https://www.epa.gov/climatechange-science/basics-climate-change
- Overview of Climate Change Science - US EPA, accessed May 5, 2025, https://19january2017snapshot.epa.gov/climate-change-science/overview-climate-change-science_.html
- Climate Change Indicators: Greenhouse Gases | US EPA, accessed May 5, 2025, https://www.epa.gov/climate-indicators/greenhouse-gases
- science.nasa.gov, accessed May 5, 2025, https://science.nasa.gov/climate-change/causes/#:~:text=Scientists%20attribute%20the%20global%20warming,energy%20coming%20from%20the%20Sun.
- What is the difference between natural global and enhanced global warming? - Quora, accessed May 5, 2025, https://www.quora.com/What-is-the-difference-between-natural-global-and-enhanced-global-warming
- Anthropogenic and Natural Radiative Forcing - IPCC, accessed May 5, 2025, https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf
- Climate Change: Global Temperature, accessed May 5, 2025, https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature
- Chapter 11: Weather and Climate Extreme Events in a Changing Climate - IPCC, accessed May 5, 2025, https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-11/
- The Effects of Climate Change - NASA Science, accessed May 5, 2025, https://science.nasa.gov/climate-change/effects/
- Climate Change 2021 - IPCC, accessed May 5, 2025, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

