THE SUMMARY FOR URBAN POLICYMAKERS OF THE IPCC'S SIXTH ASSESSMENT REPORT

VOLUME I

WHAT THE LATEST PHYSICAL SCIENCE OF CLIMATE CHANGE MEANS FOR CITIES AND URBAN AREAS

SUMMARY FOR URBAN POLICYMAKERS

The Summary for Urban Policymakers (SUP) Initiative is a series of three summary reports: *What the Latest Physical Science of Climate Change Means for Cities and Urban Areas*, distilled from the IPCC Working Group I report; *What the Latest Science on Impacts, Adaptation and Vulnerability means for Cities and Urban Areas*, distilled from the IPCC Working Group II report; and *What the Latest Science on Climate Change Mitigation Means For Cities and Urban Areas*, distilled from the IPCC Working Group III report.

This is Volume I of the series and all three are available here: https://supforclimate.com

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SUP VOLUME I

What the Latest **Physical Science of Climate Change** Means for Cities and Urban Areas

SUP VOLUME II

What the Latest Science on **Impacts, Adaptation and Vulnerability** Means for Cities and Urban Areas

SUP VOLUME III

What the Latest Science on **Climate Change Mitigation** Means for Cities and Urban Areas

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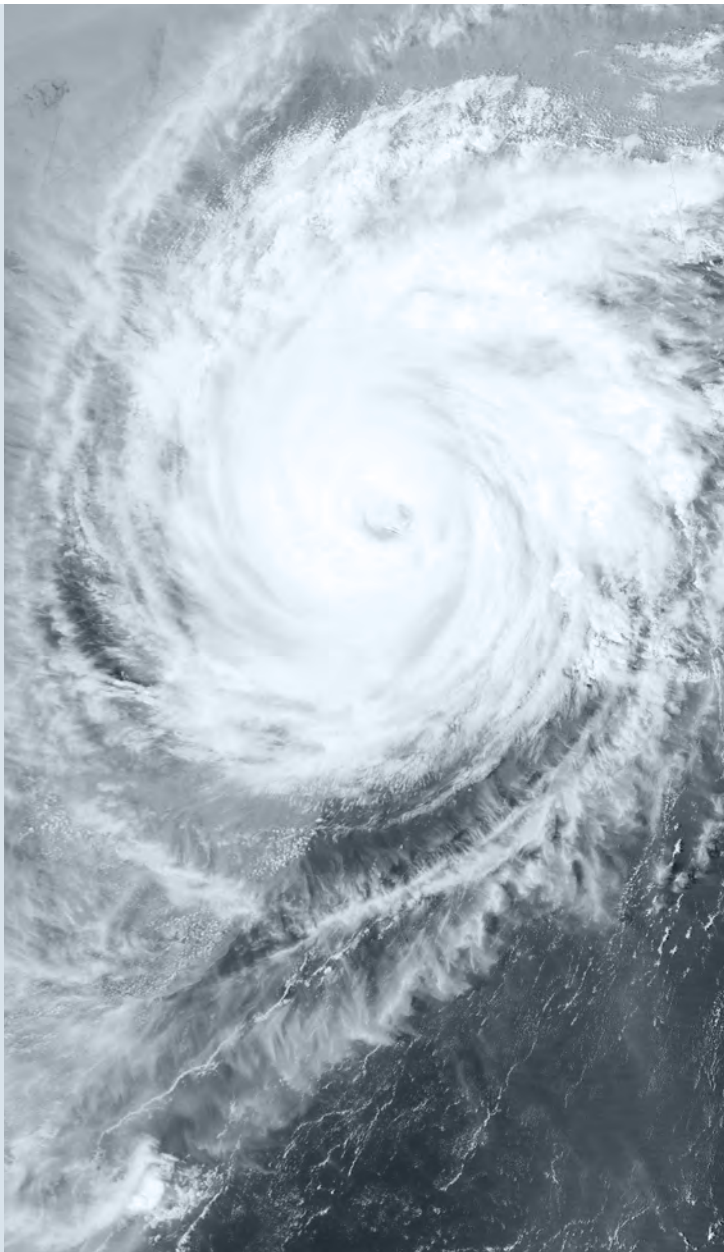

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THE SUP SERIES

The 6th Assessment Report cycle (AR6) of the Intergovernmental Panel on Climate Change (IPCC) comes at a turning point in history. Human influence has warmed the planet, and widespread and rapid impacts are occurring to both natural and human systems in all regions of the world. In response, immediate action is needed if there is to be any hope of limiting global warming close to 1.5°C or well below 2°C below pre-industrial levels, as well as preparing for and adapting to current and future risks. AR6 is composed of three main reports: *The Physical Science Basis*; *Impacts, Adaptation and Vulnerability*; and *Mitigation of Climate Change*, as well as a synthesis report. It also includes three special reports: the *Special Report on Global Warming of 1.5°C*, the *Special Report on the Ocean and Cryosphere in a Changing Climate*, and the *Special Report on Climate Change and Land*. Together they offer the most current and comprehensive scientific understanding of the climate crisis.

The transformations needed in response to climate change will require decisive action in cities and urban areas. Cities and urban areas are a major source and driver of emissions; they are also crucial sites for system transitions in the near term and transformations over longer time frames. The Summary for Urban Policymakers (SUP) initiative provides a distillation of IPCC climate reports into accessible and targeted summaries that can help inform action at the city and regional scale. The latest three volumes of the SUP series are authored by IPCC AR6 cycle authors in conversation with city officials, national governments, and business communities in every region of the world. The first volume focuses on the physical science basis of climate change, the second on managing climate risks and adaptation, and the third on mitigation. Each volume is distilled from the official IPCC reports of the AR6 cycle. While focused on each discrete IPCC working group report, the individual volumes in the SUP series bring the findings into conversation with each other. In doing so, it provides accessible science for policymakers and supports preparation for the IPCC Special Report on Cities, due in 2025 as part of the 7th Assessment cycle.

This report, *What the Latest Physical Science of Climate Change Means for Cities*, distils IPCC AR6 Working Group I material for urban policymakers. Key findings on current and future changes in the climate and their implications for urban areas include:

- With global warming reaching 1.1°C over the last decade, human-induced climate change is affecting every region of the world, and even more the cities and urban areas therein.
- In the coming decades, warming will continue to worsen, as will associated effects on cities such as drought, heavy rainfall, floods, extreme heat, storm surges, and cyclones.
- Many cities and urban areas will also experience sea-level rise and associated coastal erosion, and more frequent coastal flooding.
- Looking out to 2050, without immediate and deep reductions in emissions, global warming would exceed 2.0°C, exposing even more cities and the people, infrastructure and ecosystems therein.

As this volume and the wider series make clear, the time for cities to act, and for stakeholders to enable such action, is now.

Gwangju, South Korea

1. THE PHYSICAL SCIENCE BASIS: HISTORICAL CONTEXT, LOCAL CONTENT

In Rio de Janeiro in 1992, UN member states – or parties – agreed to the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement, concluded twenty years later at the twenty-first Conference of Parties (COP 21), committed states to reducing warming to well below 2°C. The Paris Agreement included an opening for member states to increase their efforts – known as Nationally Determined Contributions – to reduce emissions beyond those contained in the Agreement. The commitment and means to do so have been the subject of negotiations at subsequent COPs.

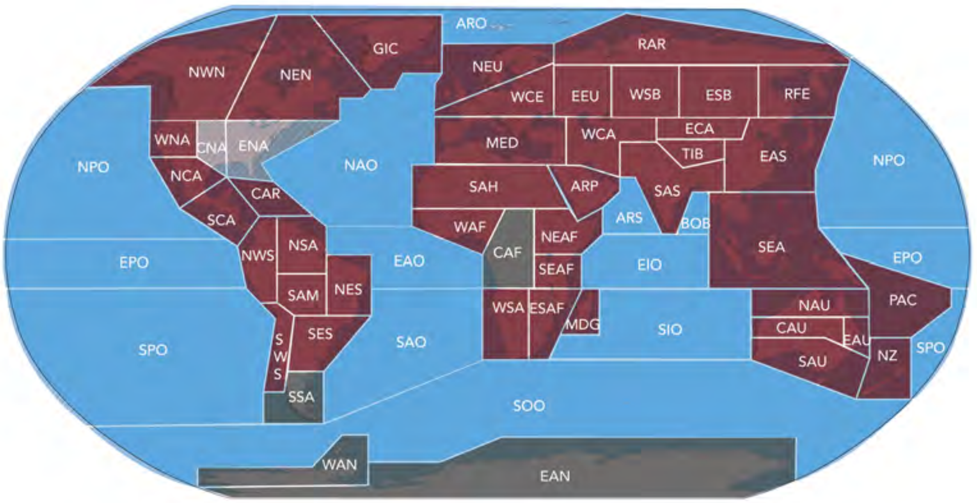
Paris, France

In addition to these commitments, COP 21 concluded with an invitation to the IPCC to deliver a special report on warming of 1.5°C.

Published in 2018, the *IPCC Special Report Global on Warming of 1.5°C (SR1.5)* assessed the impacts at different levels of warming, particularly between 1.5°C and 2°C. It made clear the dramatically different potential impacts on human health, well-being and poverty, land and ocean ecosystems, and biodiversity as warming moves above 1.5°C. Every increment, every 0.1°C, of warming matters. Overshooting 1.5°C global warming, even if only temporarily, would lead to more catastrophic impacts in an increasingly uncertain world. SR1.5 also identified four simultaneous systems transitions needed to deliver the necessary emission reductions and adaptations, including a transition in the urban and infrastructure system, in addition to those in energy; land and ecosystems; and industry systems.[1] The 2019 *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* highlighted the cascading effects of changes occurring from the highest mountains to the deepest oceans, and from polar regions to tropical and temperate coastal areas. It noted the importance of cities in those regions as sites at the frontline of climate change.[2] The Special Report on *Climate Change and Land*, also published in 2019, did not explicitly focus on urban areas, though it discussed urbanisation as a key driver of land-use change, with tradeoffs for climate mitigation.[3]

The Physical Science Basis, published in 2021, updated these assessments, including findings related to the built environment, land, and sea level rise. Important new findings around impacts from heavy rainfall; extreme heat; air pollution; compound events; and low-likelihood, high-impact outcomes also featured in the report. Due to its global scope and perspective, there are limits to the urban evidence included in *The Physical Science Basis*. However, the interactive Regional Atlas – key elements of which are captured in Figure 1 – provides context for understanding climatic impact-drivers for cities in each region.[4]

Figure 1: Climate change is already affecting every inhabited region across the globe. Human influence contributes to many observed changes (since the 1950s) in weather and climate extremes.

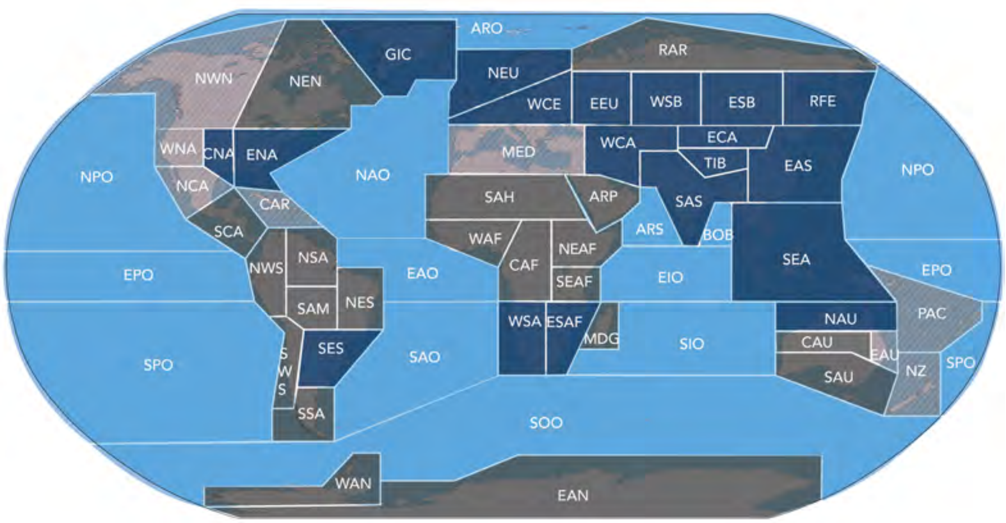


Increase

Low agreement in type of change for the region as a whole

Limited data/or literature

(a) Observed change in **hot extremes**



Increase

Low agreement in type of change for the region as a whole

Limited data/or literature

(b) Observed change in **heavy precipitation**

Source: Derived from IPCC AR6 WGI Summary for Policymakers Figure SPM.3

IPCC AR6 WGI reference regions:

NORTH AMERICA:
NWN - North-Western North America
NEN - North-Eastern North America
WNA - Western North America
CNA - Central North America
ENA - Eastern North America

CENTRAL AMERICA
NCA - Northern Central America
SCA - Southern Central America
CAR - Caribbean

SOUTH AMERICA
NWS - North Western South America
NSA - Northern South America
NES - North-Eastern South America
SAM - South American Monsoon
SWS - South-Western South America
SES - South-Eastern South America
SSA - Southern South America

EUROPE
GIC - Greenland/Iceland
NEW - Northern Europe
WCE - Western and Central Europe
EEU - Eastern Europe
MED - Mediterranean

AFRICA
MED - Mediterranean
SAH - Sahara
WAF - Western Africa
CAF - Central Africa
NEAF - North Eastern Africa
SEAF - South Eastern Africa
WEAF - South Western Africa
ESAF - East Southern Africa
MDG - Madagascar

ASIA
WSB - Western Siberia
ESB - East Siberia
RFE - Russian Far East
WCA - West Central Asia
ECA - East Central Asia
TIB - Tibetan Plateau
EAS - East Asia
ARP - Arabian Peninsula
SAS - South Asia
SEA - South East Asia

AUSTRALASIA
NAU - Northern Australia
CAU - Central Australia
EAU - Eastern Australia
SAU - Southern Australia
NZ - New Zealand

SMALL ISLANDS
PAC - Pacific Small Islands
CAR - Caribbean

OCEANS
ARO - Arctic Ocean
NPO - North Pacific Ocean
EPO - Equatorial Pacific Ocean
SPO - South Pacific Ocean
NAO - North Atlantic Ocean
EAO - Equatorial Atlantic Ocean
SAO - South Atlantic Ocean
ARS - Arabian Sea
BOB - Bay of Bengal
EIO - Equatorial Indian-Ocean
SIO - South Indian-Ocean
SOO - Southern Ocean

POLES
RAR - Russian Arctic
WAN - West Antarctica
EAN - East Antarctica

The Physical Science Basis also builds on recent methodological advancements of particular value for urban practitioners and policymakers. Relevant and robust local information on climate change is increasingly needed and demanded for integrated adaptation and mitigation planning and action at the city scale, and to enable local decision making around the implementation of sustainable development. As Box 1 makes clear, for information to be both robust and reliable, multiple lines of evidence must be drawn upon, including different models and process understanding, observational data, and attribution.[5] Despite some identified knowledge gaps, there is significant material in *The Physical Science Basis* that can be useful for cities in the construction of their adaptation plans, including, for example, new urban modules developed to calculate the exchanges of heat and water between the urban fabric and its overlying atmosphere.[6] That material, and that which is relevant to mitigation, is covered below.

Localisation Methodology - constructing climate change information for cities

Fires, flooding, and tropical cyclones, among other extreme events, have struck cities around the world in recent years. For the risk assessment and adaptation action necessary to meet these challenges, policymakers need to understand the relationship between extreme conditions and climate change on the city scale. For regional climate change information to be robust and reliable, providing a well-grounded analytic foundation for policymakers, it should be based on multiple lines of evidence. These include: different types of observations, including local or indigenous knowledge; attribution of trends and events; different types of climate models; and expert knowledge on climatic processes.

Different types of observations are crucial to evaluate the past performance of diverse types of climate models that are used to project future climate impacts or to attribute specific and already experienced outcomes to the changing climate. Long-term observational records are crucial to assess if the types of extreme events of interest have become more common or intense over time. Diverse climate models can be more appropriate for different regions and to explore different types of questions about the future. In this sense it is important that the climate models employed to answer a specific question for a specific city represent the physical processes that are most relevant for that particular context.

For regional climate change information to be useful and relevant for integration in decision-making, co-production of information is a viable and efficient approach. In co-production the context and the values of the user and the scientists are taken into account in an explicit manner. Working together, data can be translated at a scale and with associated degrees of certainty to inform policymaking, while identifying the demand for specific new information that can be used to explore the future. City-scale climate monitoring networks, for example, enhance the understanding of the urban heat island and its interaction with climate change and provide key information for end users such as urban planners, policymakers, stakeholders, and the general public.[7] These approaches can increase use of data in urban policy decision-making and inform investments in improved climate modelling approaches.

Box 1.

Shenzhen, China

1. WHAT THE PHYSICAL ASPECTS OF CLIMATE CHANGE MEANS FOR CITIES

Based on an unprecedented volume of evidence, *The Physical Science Basis* presents the consequences of human influence on climate change, and hence the planet. Amid the rigorous science and nuanced findings contained in the report, a number of essential, and unequivocal, messages emerge.

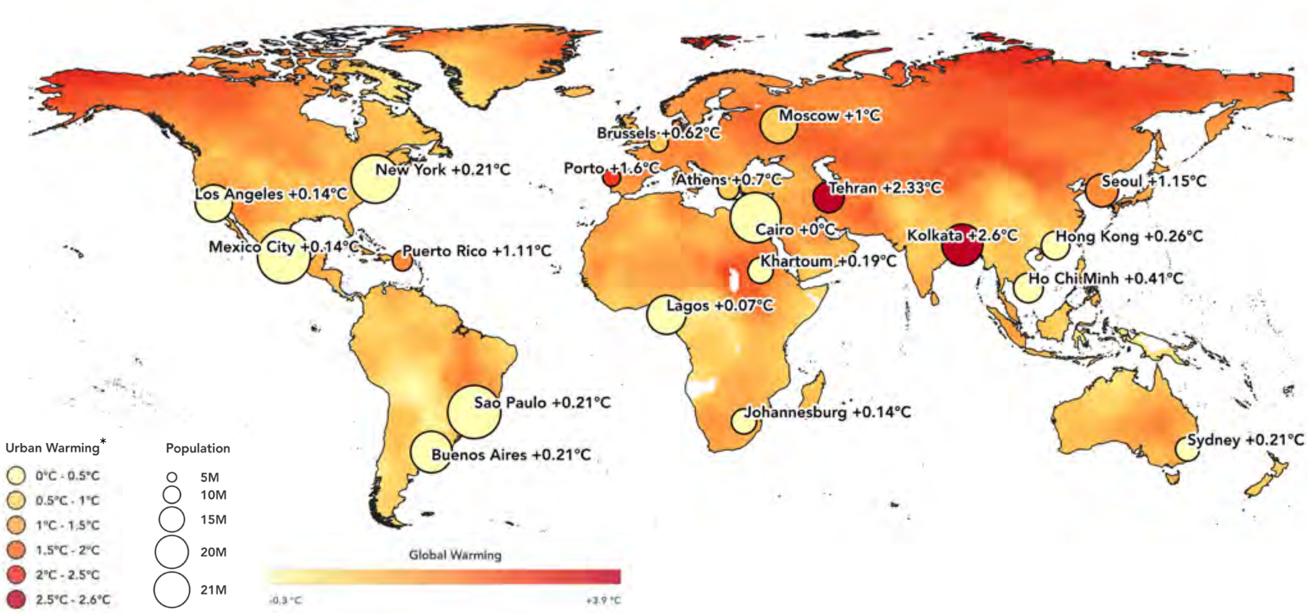
The climate change crisis is here. Human-induced climate change is increasingly affecting every region of the world, including through more intense weather and climate extremes. From a physical perspective, reducing human-caused global warming is possible by achieving net-zero CO_2 emissions combined with a sharp reduction of emissions from other greenhouse gases (GHG), in particular methane.

However, without immediate and deep reductions in GHG emissions, global warming will exceed 2°C by around 2050. Even with strong reduction of emissions the cumulative CO_2 emissions will increase and exceed 1.5°C in the next 20 years. The effects of historical GHG emissions will also be long lasting. Many of the changes, particularly with regards to the ocean, ice sheets, and global sea level rise, will last for centuries to millennia.

The rapidly changing climate, and climate-induced risks in particular, have profound implications for cities. Many of these track the key findings of *The Physical Science Basis*, only in more severe terms as the effects of climate change are often exacerbated in cities, particularly with regards to temperature increases. Observed warming is larger over land than the ocean, and therefore some large cities in West and South Asia and smaller cities in the Arctic have already exceeded 2°C (for 1.1°C of global warming). Even with strong reductions in emissions, many cities and urban areas will be increasingly exposed to more frequent drought, floods, extreme heatwaves and storm surge, as well as

Cairo, Egypt

Figure 2: Past trends in global surface air temperature (1958-2018) with cities reporting significant temperature increases.



*Urban Warming refers to the difference between local urban temperature change and surrounding warming.

Source: Change in the annual mean surface air temperature over the period 1958-2018 based on the local linear trend retrieved from CRU TS (°C per 68 years). This map has been amended from IPCC 2021, Climate Change 2021: The Physical Science Basis, Chapter 10: Linking Global to Regional Climate Change; United Nations, Department of Economic and Social Affairs, Population Division (2018); World Urbanization Prospects: The 2018 Revision, Online Edition.

more intense cyclones. Given the long life cycles of many urban and infrastructure systems, sea level rise will continue to have increasing implications even if warming is stabilised.

Climatic impact-drivers are climate-related means or events that impact societies and ecosystems. The temporal horizon of climatic impact-drivers runs on a continuum from rapid-onset events that may occur in hours or days to slow-onset events that evolve over many years as a result of an increased frequency and intensity of events. Climatic impact-drivers are increasing across all regions, and individual extreme events are increasing in frequency, intensity, and impact. Every region will experience concurrent and multiple changes in climatic impact-drivers at higher levels of global warming. In many places, these climatic impact-drivers are arriving simultaneously, in compound events, and overlapping with slow-onset drivers. A summary of key climatic impact-drivers in cities and urban areas is provided below.

Without immediate and deep reductions in GHG emissions, global warming will exceed 2°C by around 2050. Even with strong reduction of emissions the cumulative CO_2 emissions will increase and exceed 1.5°C in the next 20 years. Observed warming is larger over land than the ocean, and therefore some large cities in West and South Asia and smaller cities in the Arctic have already exceeded 2°C (for 1.1°C of global warming).

Precipitation and floods

Human-induced global warming is dramatically altering the global water cycle. Atmospheric moisture and precipitation intensity have increased, as has the transfer of water from soil to the atmosphere. Patterns of aridity have also been influenced by human-induced warming. Hydrological extremes – from water cycle variability to precipitation to tropical and extratropical cyclones – are going to continue and intensify.[8]

Studies at the regional scale, while not necessarily narrowed to the city level, offer specific insights into observed and anticipated changes in precipitation:

- Significant increasing trends in mean precipitation have been observed over some northern high-latitude regions. Meanwhile, decreasing trends have been observed over regions in tropical Africa, the Americas, and Southwest Asia.
- In high altitudes, total precipitation will increase, shifting from snowfall to rainfall except in the coldest regions and seasons. Meanwhile, total precipitation will decrease in a significant number of regions, including over the Mediterranean, Southern Africa, Amazonia, Central America, southwestern South America, southwestern Australia, and coastal West Africa.
- In mountains, in particular, surface and groundwater are likely to be impacted by the shift in precipitation from snow to rain. In South Asia and other regions where snowmelt is the primary source of runoff, this shift can lead to declines in streamflow and groundwater storage.
- Impacted areas include South America, and Northern North America, and the mountains of Asia.

Cities and urban areas are particularly vulnerable to floods owing to impervious surfaces and sealed soils that do not retain sufficient water. If impervious surfaces rise to 50-90% of the urban terrain, then 40-83% of rainfall becomes seasonal runoff. Heavy rain events can flood buildings, roadways, subway tunnels, and farmlands. Heavy precipitation may overwhelm metropolitan transportation and stormwater drainage systems, which are typically designed to withstand specific event intensity, duration, and frequency that can be exceeded by many climate-induced extreme events.[9]

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New Orleans, USA

Monsoons and cyclones

A warmer climate will intensify very wet and very dry weather, as well as climate events and seasons, with implications for flooding or drought. However, the location and frequency of these events depend on changes in regional atmospheric circulation, including monsoons and mid-latitude storm tracks.

Monsoon precipitation, though complex, is projected to increase in the midterm to long term at the global scale, with a delayed onset over North America, South America, and West Africa and a delayed retreat over West Africa.[10] Monsoon precipitation will increase over South Asia, East Asia and central-eastern Sahel.[11]

Tropical cyclones bring intense winds, heavy rainfall, and flooding amplified by storm surges to cities and urban areas. There has been an increase in the proportion of the most intense tropical cyclones, and the average peak wind and heavy rainfall of tropical cyclones will also increase with further global warming.[12] Sea level rise, an increased proportion of the most intense cyclones, and increased heavy rainfall associated with coastal storms, will expose cities to compound wind, water, and coastal hazards with the potential for widespread human mortality and damage to housing, transportation, and energy infrastructure.[13]

Sea level rise, an increased proportion of the most intense cyclones, and increased heavy rainfall associated with coastal storms, will expose cities to compound wind, water, and coastal hazards with the potential for widespread human mortality and damage to housing, transportation, and energy infrastructure.

Puchong, Malaysia

Drought and aridity

As warming advances, droughts will become more frequent and severe, while impacting more total land area.[14] Droughts do differ in impact and response to GHG concentrations, and thus drought trends differ by region. For example:

- Over the last decade, the areas impacted by extreme meteorological drought in the Mediterranean, western North America, southwestern Australia, Southern Africa, and southwestern South America have increased.
- Regions that have shown increases in drought due to lack of rain are found in Africa and South America.
- In semi-arid areas with existing water availability constraints, drought is a major climatic impact-driver. On all continents, there are observed increases in agricultural and ecological drought.
- Soil moisture drought also increases water scarcity and damages to buildings.
- Looking forward, droughts in arid and semi-arid areas are likely to increase.[15]

Droughts, whether meteorological, hydrological, agricultural, or ecological, and while differing by region, significantly impact cities. Drought can lead to increased groundwater withdrawal and thus depletion. For coastal cities and urban areas, heat island effect worsens drought and aridity. A warming climate combined with human groundwater use, including in cities, will deplete groundwater resources in already dry regions.[16] Notably, ecological droughts can lead to disruption in food production, thus directly affecting cities.

Heat

Cities and urban areas are experiencing an increase in heatwaves. There are now more hot days, and they are hotter, and fewer cold days and nights. Heatwaves have increased in both duration and intensity, and these increases, along with a decrease in the intensity and frequency of cold extremes, will continue throughout the 21st century.

Cities and urban areas are experiencing an increase in heatwaves. There are now more hot days, and they are hotter, and fewer cold days and nights.

Istanbul, Turkey

Brighton, UK

Sea level and storm surges

Sea level and air temperature rises are projected in most coastal cities and urban areas. Changes in relative sea level, storm surges, and ocean waves meet with other drivers such as extreme precipitation and river flooding. Consequently, coastal flooding with increased recurrence and intensity of extreme sea levels will lead to increased erosion for cities in low-lying areas.[17]

There will be long-term impacts resulting from rising sea levels. The rise in sea level will continue beyond 2100 - and the impacts continue for centuries to millenia, but the pace of this rise will strongly depend on future emissions.[18] Increased warming will also lead to a decrease in seasonal snow cover and surface permafrost thaw. In high-latitude and mountain regions, thawing may destabilise settlements and critical infrastructure.

Air quality

Air quality has a significant impact on the health of local residents. However, the evidence linking climate change and air quality is mixed. In already heavily-polluted environments, some climate-driven changes in meteorological conditions can favour extreme air pollution episodes. Climate change induced disruptions, such as wildfires near cities, are likely to deteriorate air quality at local and regional scales, but remain difficult to project and quantify.[19] A warmer climate is expected to increase mean surface ozone over polluted regions, which could prove detrimental and significant to human health. This enhancement grows with the level of emissions of ozone precursors. For the most part, future air quality will be primarily driven by changes in precursor emissions as opposed to climate change.

Compound events

For cities and urban areas, it is important to consider equally discrete events; compound events; and low-probability, high-impact events.[20] When combined in close succession, or concurrently in different regions, non-extreme events can lead to extreme impacts that far exceed the impact of individual events.[21] In many cities and low-lying areas, concurrent storm surges and high river flows have led to compound flooding. Such events are projected to increase in frequency, as are wildfires from compound hot, dry, and windy events. Meanwhile, interactions between urban heat islands and extreme heat episodes make heatwaves more intense in urban than rural areas, particularly at night.

When combined in close succession, or concurrently in different regions, non-extreme events can lead to extreme impacts that far exceed the impact of individual events.


Jakarta, Indonesia


Canberra, Australia

2. WHAT HAPPENS IN CITIES MATTERS

As *The Physical Science Basis* lays out, cities, urban areas, and urbanisation processes are key drivers of how climate change manifests over and around urban areas.

Urbanisation can impact overall precipitation patterns in and near cities. This is true for average rainfall, and especially for heavy precipitation. Extreme precipitation, especially at high levels of global warming, will lead to the most serious impacts, including an increase in flood risks. Urbanisation also brings about changes to the water cycle that lead to increasing surface runoff intensity.[22] Finally, short-term solutions to reduce air pollution in urban centres that do not adequately consider associated emissions impacts can further exacerbate the impact of climate change both at the city scale and globally.

The impact of cities, urban areas, and urbanisation on the key drivers of climate change is perhaps nowhere more evident than when it comes to heat. The combination of future urbanisation and increasingly frequent extreme climate events, such as heatwaves, will have significant implications for heat stress in cities.[23] The urban heat island effect is caused by a number of factors, with

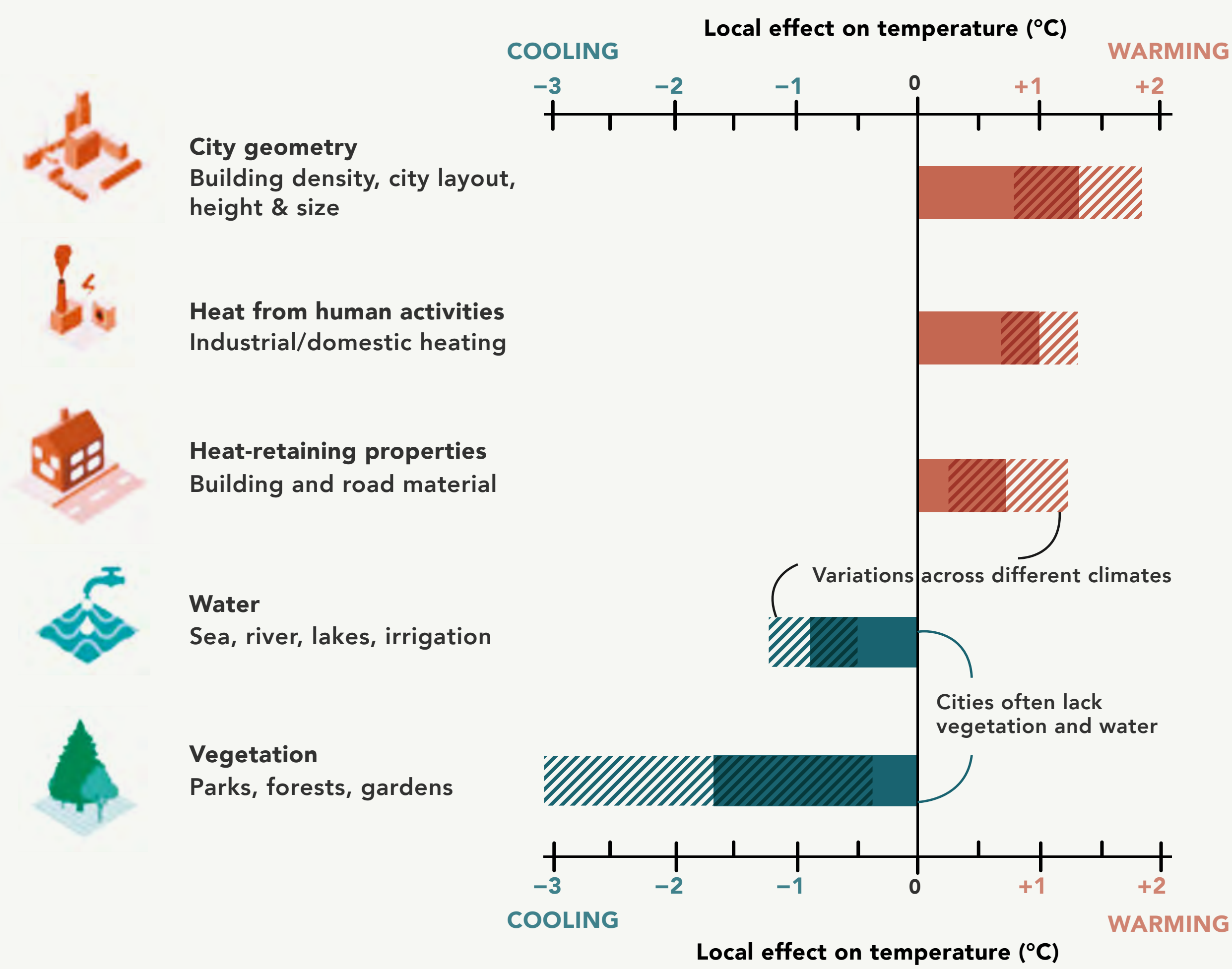
The combination of future urbanisation and increasingly frequent extreme climate events, such as heatwaves, will have significant implications for heat stress in cities.

Santiago, Chile

urban geometry being the strongest contributor. The number of buildings, and their size and their proximity, matters. Tall, proximate buildings absorb and store heat while reducing natural ventilation. The heat-retaining properties of the materials that make up concrete buildings, asphalt roadways, and dark rooftops – constituent parts of many cities – also adds to warming. These materials absorb and retain heat during the day, and re-emit that heat at night. Concentrated in cities and urban areas, human activities directly warm the local atmosphere through heat released from domestic and industrial heating or cooling systems, running engines, and other sources.

An absence of vegetation and water bodies, which can strongly contribute to local cooling, can further amplify the urban heat island effect. Looking forward, urbanisation will intensify urban heat island effects regardless of changes in the background climate.[24] However, sufficient integration of vegetation and water into the urban fabric can partially counterbalance the effect.[25] Urban greening, meanwhile, as well as urban and peri-urban agriculture, can potentially lessen the impacts of urban heat island and warming. Urbanisation can also induce the urban dryness island effect, when humidity in cities and urban areas drops below that of more rural areas.[26]

Figure 3: Cities are usually warmer than their surrounding areas due to factors that trap and release heat and a lack of natural cooling influences such as water and vegetation.



Source: Derived from IPCC AR6 WGI Chapter 10, FAQ10.2

CONCLUSION: LOOKING FORWARD

The Physical Science Basis offers the most current and comprehensive scientific understanding of changes to the physical world as a result of human activities. Even with drastic reductions in GHG emissions, global warming of 1.5°C will be exceeded in this century. Such warming increases both the frequency and severity of extreme weather and high-impact events whose effects are exacerbated in cities and urban areas. We must act now to adapt to those changes and mitigate the emissions driving them. The science makes strikingly clear that cities and urban areas are at once sources of climate forcers and important sites for innovation, adaptation, mitigation, and the implementation of sustainable development. With urban-related policies set not only by city officials, but also by policymakers at local, regional, and national levels, there is a considerable responsibility on, and opportunity for, urban policymakers at all levels of government to address the climate crisis.

Cities and urban areas face multiple, compounding risks and impacts that increase exponentially and disproportionately at higher warming levels. With an understanding of attribution and risks comes an imperative to act on opportunities and options for climate action. Systems transitions are needed to limit climate impact, including rapid and concurrent transitions in energy; land, ocean, coastal, and freshwater ecosystems; industry and society; as well as urban, rural and infrastructure systems.[27] The IPCC Working Group II report *Impacts, Adaptation and Vulnerability*, focuses on the risks climatic impact-drivers pose to lives, livelihoods, ecosystems, and biodiversity, arguing/showcasing how cities are frontrunners in adaptation action. Together with the IPCC's Working III report on *Mitigation of Climate Change*, the global community has a map of the solution space on climate change and sustainable development, with cities playing a central role in how we adapt and mitigate.

The global community has a map of the solution space on climate change and sustainable development, with cities playing a central role in how we adapt and mitigate.

Kolkata, India

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IMAGE CREDITS

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