# IPCC Sixth Assessment Report a Short Summary of Highlights

## Climate Change 2021: The Physical Science Basis

On August 9th 2021, the Intergovernmental Panel on Climate Change (IPCC) published a major report on the physical changes to the climate that have already occurred and are projected to occur as a result of human activity. This is an update on their previous assessment which was published in 2013.

### Introduction

There are three things you need to know before reading this document or the original 41-page Summary for Policymakers.

- This document has been gone through word by word, line by line, and paragraph by paragraph to get a version agreed upon by almost all governments in the world
- Key findings are formulated as statements of fact, or associated with an assessed level of confidence using IPCC calibrated language:
    - *Virtually certain = 99-100% probable*
    - *Extremely likely = 95-100% probable*
    - *Very likely = 90-100% probable*
    - *Likely = 66-100% probable*
- Turning to the Summary itself, there are, under 4 broad headings, 14 headline statements, each of which is backed up by a selection of key scientific findings. The headline statements are in bold

You can download the Summary for Policy Makers using the following link: Climate Change 2021: The Physical Science Basis - Summary for Policy Makers.

Alternatively, use the following link: AR6 Climate Change 2021: The Physical Science Basis takes you to a page where, in addition to the summary report, you can access a press release and two informative presentation slide decks as well as the full version of the report (approx 1,300 pages!).

**Notes**

IPCC Assessment Reports come in groups of three. The current report "**Climate Change 2021: Physical Science Basis**" outlines the current known situation and future projected impacts of five emissions scenarios, which range from global net negative and net-zero to emissions doubling by 2050 and 2100, compared to current levels. The second report "**Climate Change 2022: Impacts, Adaptation and Vulnerability**" is scheduled for publication in February 2022, and the third report "**Climate Change 2022: Mitigation of Climate Change**" is scheduled for publication in March 2022".

# A Few of Key Points from the IPCC Report:

## Climate Change 2021: The Physical Science Basis - Summary for Policy Makers

*For full details please refer to the relevant section of the "Summary for Policy Makers" as indicated by the section letters and number below.*

### A: The Current State of the Climate

**A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred**

- The *likely* range of human-caused global surface temperature increase (from the 1850-1900 average) is 0.8°C-1.3°C with a best estimate of 1.07°C. This is the amount of warming already caused
- Globally averaged precipitation over land (i.e. rainfall) has *likely* increased since 1950 with a faster rate of increase since 1980
- Mid-latitude storm tracks have *likely* shifted poleward in both hemispheres since the 1980s, with marked seasonality in trends
- Human influence is *very likely* the main driver in the global retreat of glaciers since the 1990s, in the decrease of Arctic sea ice, in the decrease in Northern Hemisphere spring snow cover, and the observed surface melting of the Greenland ice sheet
- It is *virtually certain* that the upper ocean has warmed since the 1970s and *extremely likely* that human influence is the main driver. It is *virtually certain* that human-caused $CO_2$ emissions are the main driver of current global acidification of the ocean
- Global mean sea level increased between 1901 and 2018 by 0.2 metres. Human influence was *very likely* the main driver of these increases since at least 1971

**A.2 The scale of recent changes across the climate system as a whole, and the present state of many aspects of the climate system are unprecedented in the last many thousands of years**

- In 2019, atmospheric $CO_2$ concentrations were higher than at any time in at least 2 million years, and this increase far exceeds the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years
- Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2,000 years
- In recent years annual average Arctic sea ice reached its lowest level since at least 1850. The global nature of glacier retreat since the 1950s is unprecedented in at least the last 2,000 years
- Global mean sea-level has risen faster since 1900 than over any preceding century in at least the last 3,000 years. The global ocean has warmed faster over the past century than since the end of the last ice age

**A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones and, in particular, their attribution to human influence, has strengthened since AR5 (the fifth IPCC Report)**

- It is *virtually certain* that heatwaves have become more frequent and more intense across most land regions since the 1950s, while cold extremes have become less frequent and less severe, with *high confidence* that human-induced climate change is the main driver
- The frequency and intensity of heavy rainfall events have increased since the 1950s over most land areas (*high confidence*) and human-induced climate change is *likely* the main driver
- It is *likely* that the proportion of tropical cyclones that are classified as major (Category 3-5) has increased over the past 4 decades
- Human influence has *likely* increased the chance of compound extreme events (e.g. heatwaves plus droughts) and of catastrophic fires and compound flooding

**A.4 Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a revised best estimate of equilibrium climate sensitivity of 3°C**

- The equilibrium climate sensitivity (ECS) is the amount of global temperature increase that would be caused by a doubling of the $CO_2$ levels in the atmosphere, relative to pre-industrial levels. The best estimate now of ECS is 3°C. This is the amount of global warming that would eventually be caused by a doubling of $CO_2$ levels, which could take hundreds or possibly thousands of years

## B. Possible Climate Futures

The IPCC Report models 5 different scenarios based on future emissions causing different degrees of warming:

| | | |
|---|---|---|
| Scenario SSP1-1.9 | Very Low | emissions fall rapidly from now to net-negative |
| Scenario SSP1-2.6 | Low | emissions fall from now to net-zero by 2050 |
| Scenario SSP2-4.5 | Intermediate | emissions level off and fall from 2050 |
| Scenario SSP3-7.0 | High | emissions double by 2100 |
| Scenario SSP5-8.5 | Very High | emissions double by 2050 |

### B.1 Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in $CO_2$ and other greenhouse gas emissions occur in the coming decades

- Under the Very Low scenario, global surface temperature over the 2081-2100 period is *very likely* to be higher by 1.0°C-1.8°C compared to 1850-1900
- Under the Intermediate Scenario, global surface temperature over the 2081-2100 period is *very likely* to be higher by 2.1°C-3.5°C compared to 1850-1900
- Under the Very High Scenario, global surface temperature over the 2081-2100 period is *very likely* to be higher by 3.3°C-5.7°C compared to 1850-1900
- The last time global surface temperature was sustained at or above 2.5°C higher than 1850-1900 was over 3 million years ago

Based on the assessment of multiple lines of evidence, the best estimates for global warming under the five scenarios are as follows (in degrees C):

| Scenario | Near Term 2021-2040 | Mid Term 2041-2060 | Long Term 2081-2100 |
|---|---|---|---|
| Very Low | 1.5 | 1.6 | 1.4 |
| Low | 1.5 | 1.7 | 1.8 |
| Intermediate | 1.5 | 2.0 | 2.7 |
| High | 1.5 | 2.1 | 3.6 |
| Very High | 1.6 | 2.4 | 4.4 |

**B.2 Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts, as well as reductions in Arctic sea ice, snow cover and permafrost**

- It is *virtually certain* that the land surface will continue to warm more than the ocean surface. It is *virtually certain* that the Arctic will continue to warm more than global surface temperature, with *high confidence* above two times the rate of global warming
- With every additional increment of global warming, changes in extremes become larger
- Some mid-latitude and semi-arid regions are projected to see the highest increase in the temperature of the hottest days
- The Arctic is projected to experience the highest increase in the temperature of the coldest days
- Heavy precipitation events are very likely to intensify and become more frequent in most regions
- Additional warming is projected to further amplify permafrost thawing
- The Arctic is *likely* to be practically sea ice-free in September at least once before 2050
    - *This section also contains details, maps and diagrams that cannot be readily summarised.*

**B.3 Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events**

- Precipitation and surface water flows are projected to become more variable over most land regions, both within seasons (*high confidence*) and from year to year (*medium confidence*)
- A warmer climate will intensify very wet and very dry weather, with implications for flooding and droughts (*high confidence*)
- Monsoon precipitation is projected to increase in the mid to long term globally

**B.4 Under scenarios with increasing $CO_2$ emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of $CO_2$ in the atmosphere**

- The proportion of emissions taken up by land and ocean decrease with increasing cumulative $CO_2$ emissions
- Additional ecosystem responses to warming that are not yet fully incorporated into climate modelling include methane ($CH_4$) fluxes from wetlands, permafrost thaw, and smoke from wildfires

**B.5 Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets, and global sea-level**

- Based on multiple lines of evidence, upper ocean stratification (*virtually certain*), ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the 21st century, at rates dependent on future emissions
- Mountain and polar glaciers will continue melting for decades or centuries (*very high confidence*). Loss of permafrost carbon from permafrost thaw is irreversible at centennial timescales (*high confidence*). Continued ice loss over the 21st century is *virtually certain* for the Greenland ice sheet and *likely* for the Antarctic ice sheet
- It is *virtually certain* that the global mean sea level will continue to rise over the 21st century, by between 0.5 and 1.0 metres depending on future emissions
- In the longer term, the sea level will rise for centuries to millennia due to continuing deep ocean warming and ice sheet melt and it will remain elevated for thousands of years. Over the next

2000 years, the global mean sea level will rise by 2-3 metres if warming is limited to 1.5°C, 2-6 metres if warming is limited to 2°C and 19-22 metres with 5°C of warming

## C. Climate Information for Risk Assessment and Regional Adaptation

**C.1 Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes**

- Variations in solar and volcanic drivers partially masked human-caused global surface warming during 1998-2012, with pronounced regional and seasonal signatures. Nonetheless, the heating of the climate system continued during this period, as reflected in both the continued warming of the global ocean (*very high confidence*) and in the continued rise of hot extremes over land (*medium confidence*)
- Near term cooling at any particular location with respect to the present climate could occur and would be consistent with the global surface temperature increase due to human influence
- It is likely that at least one large explosive volcanic eruption would occur during the 21st century. Such an eruption would reduce global surface temperature and precipitation, especially over land, for one to three years

**C.2 With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climate-impact drivers (CID's). Changes in several CID's would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels**

- All regions are projected to experience further increases in hot climate impact drivers (CID's) and decreases in cold CID's. Extreme heat thresholds relevant to agriculture and health are projected to be exceeded more frequently
- Heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia (*high confidence*), North America (*medium to high confidence*) and Europe (*medium confidence*)
- More CID's across more regions are projected to change at 2°C and above compared to 1.5°C global warming
- It is *very likely to virtually certain* that regional mean relative sea-level rise will continue throughout the 21st century
- Cities intensify human-induced warming locally, and further urbanisation together with more frequent hot extremes will increase the severity of heatwaves (*very high confidence)*
- Many regions are projected to experience an increase in the probability of compound events – in particular concurrent heatwaves and droughts are *likely* to become more frequent

**C.3 Low-likelihood outcomes such as ice sheet collapse, abrupt ocean circulation changes, some compound extreme events and warming substantially larger than the assessed *very likely* range of future warming cannot be ruled out and are part of risk assessment**

- The probability of high-impact outcomes at global and regional scales increases with higher global warming levels (*high confidence*). Abrupt tipping points such as strongly increased Antarctic ice sheet melt, and forest dieback globally, cannot be ruled out (*high confidence*)
- The Gulf Stream is *very likely* to weaken over the 21st century for all emission scenarios, although an abrupt collapse is unlikely

## D. Limiting Future Climate Change

**D.1 From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative $CO_2$ emissions, reaching at least net zero $CO_2$ emissions, together with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in $CH_4$ (methane) emissions would also improve air quality**

- This Report reaffirms with high confidence the previous finding (in 2013) that there is a near-linear relationship between cumulative anthropogenic $CO_2$ emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative $CO_2$ emissions is assessed to *likely* cause an increase in global surface temperature of 0.45°C (best estimate)
- Since 1850 a total of 2390 $GtCO_2$ of anthropogenic $CO_2$ was emitted. Remaining carbon budgets can thus be estimated for several global temperature limits
- Anthropogenic $CO_2$ removal has the potential to remove $CO_2$ from the atmosphere and durably store it in reservoirs (*high confidence*). Such removal leading to global net negative emissions would lower the atmospheric $CO_2$ concentration and reverse ocean acidification (*high confidence*)
- If global net negative $CO_2$ emissions were to be achieved and sustained, the global surface temperature increase would gradually be reversed but other climate changes would continue in their current direction for decades to millennia (*high confidence*)
- Achieving global net-zero $CO_2$ emissions is a requirement for stabilising the global surface temperature increase

**D.2 Scenarios with very low or low GHG emissions lead within around 20 years to discernible effects on greenhouse gas concentrations, and on air quality, relative to high and very high GHG emissions scenarios. Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers**

- Emissions reductions in 2020 associated with COVID-19 measures led to a temporary but detectible effect on air quality, but atmospheric $CO_2$ continued to rise in 2020, with no detectable decrease in the observed $CO_2$ growth rate (*medium confidence*)
- Such improvements in air quality are not sufficient in many polluted regions to achieve air quality guidelines specified by the WHO
- For global surface temperature, differences in 20-year trends would likely emerge during the near term under the very low emission scenario. The response of many other climate variables would emerge from natural variability at different times later in the 21st century
- Scenarios with very low or low GHG emissions would lead to substantially smaller changes in a range of CIDs beyond 2040 than under high and very high emissions scenarios