

IPCC climate science

The twelve key points you need to know

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Climate Change - Global

- ◆ IPCC report makes the science of climate change crystal clear
- ◆ Paris goals will be missed without deep & rapid emissions cuts
- ◆ We think this report provides investors with an even stronger case to demand more action from businesses & governments

Sixth time serious. The UN's climate science body, the Intergovernmental Panel on Climate Change (IPCC), has released the first of a series reports as part of its sixth assessment cycle (AR6). The report finds that **"It is unequivocal that human influence has warmed the atmosphere, ocean and land."** In general, the "uncertain ranges" for many estimates and models have narrowed – which brings an added gravitas to the messages laid out by the IPCC in its latest findings.

Nowhere to hide. The IPCC report, delayed by COVID-19, incorporates updated science from the past eight years. It offers the latest estimates on how much the climate has changed; how much more the climate could change in the future; the risks across various regions; and whether limiting further change is possible. One key message is that changes have been observed in **"every region and across the whole climate system"**. In our view, this should be yet another 'wake-up call' for governments to set ambitious, credible climate targets that cover both mitigation and adaptation along with policies that can be implemented as soon as possible.

Around the corner. We think the market will demand much more of businesses: For those in high-carbon activities to rethink business models and strategies; for industries to be more innovative in lower carbon solutions; for all segments of the economy to prepare for the impacts of climate change. With attention rapidly turning to COP26 in November, climate change will remain high on the agenda as the 'make-or-break' discussions occur before the next AR6 reports come in early 2022.



Wai-Shin Chan, CFA
Head, Climate Change Centre; Head, ESG Research
The Hongkong and Shanghai Banking Corporation Limited

Polo Heung
Associate, ESG Research
The Hongkong and Shanghai Banking Corporation Limited

Tarek Soliman*, CFA
Analyst
HSBC Bank plc

Lucy Acton, CFA
ESG Analyst
HSBC Bank plc

Anushua Chowdhury*
Associate
Bangalore

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Figure 1: Twelve key findings from the IPCC's Physical Science Basis report

| Twelve key findings from the IPCC's AR6 WG1 | |
|--|--|
| 1. The human influence on the climate can now be better attributed | 7. Warming increases the frequency and intensity of extreme events |
| 2. Atmospheric concentrations of GHGs are really high | 8. Carbon sinks only work to a certain extent |
| 3. Temperatures are rising 1.4-1.7x faster on land than oceans | 9. Tipping points are irreversible changes over centennial or millennial time scales |
| 4. Precipitation will become more frequent and more intensive | 10. Highly disruptive events "cannot be ruled out" |
| 5. Sea levels are rising faster than before | 11. The carbon budget is running out |
| 6. Climate sensitivity is "near-linear" | 12. Regional effects are a lot more nuanced |

Source: HSBC (based on IPCC, AR6 SPM)

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The science of climate change according to the IPCC

Box 1: What is the IPCC?

The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by two UN agencies (The World Meteorological Organisation, WMO; and the UN Environment Programme, UNEP) to assess the science relating to climate change. It publishes the Climate Assessment Reports every 6-7 years. The previous series of reports was the fifth assessment cycle (AR5) and were published over 2013-14. This series of reports is part of the sixth assessment cycle (AR6).

The IPCC consists of hundreds of scientists from a wide range of countries. The body does not conduct its own research but instead assesses the latest scientific papers on the topics in question. Lead authors, nominated by countries, lead reviews with many other scientists. Assessments are subject to multiple drafts and reviews before they are adopted by scientists in conjunction with governments.

Box 2: What is the Sixth Assessment or AR6?

This “Working Group I report on the Physical Science Basis” is part of the IPCC’s sixth assessment cycle (AR6). This sixth assessment cycle¹ has already seen the release of three special reports and a refined methodology. The final reports will consist of:

- ◆ Working Group 1 (WG I): The Physical Science Basis (August 2021)
- ◆ WG II: Impacts, Adaptation and Vulnerability (February 2022)
- ◆ WG III: Mitigation of Climate Change (March 2022)
- ◆ AR6 Synthesis report (September/October 2022)

Box 3: IPCC terminology (likelihood and confidence)

The IPCC uses specific terminology in describing how it reaches a finding. These are described in terms of ‘confidence’ and ‘likelihood’. According to the IPCC, the confidence in the validity of a finding is based on “the type, amount, quality, and consistency of evidence...and the degree of agreement”. These are expressed qualitatively in the form of: very low, low, medium, high, very high – confidence. For likelihood, these indicated the “assessed likelihood of an outcome or result” (Table 1).

Table 1: Likelihood scale used by the IPCC

| Term | Likelihood of the Outcome | Term | Likelihood of the Outcome |
|------------------------|---------------------------|------------------------|---------------------------|
| Virtually certain | 99-100% probability | Unlikely | 0-33% probability |
| Very likely | 90-100% probability | Very unlikely | 0-10% probability |
| Likely | 66-100% probability | Exceptionally unlikely | 0-1% probability |
| About as likely as not | 33 to 66% probability | | |

Source: IPCC AR6 methodology

A compendium of eight years of climate science

This WG I report is a compendium of updated climate science since the last report (AR5) and runs to almost 4,000 pages. It incorporates more observations, more advanced climate modelling, and touches more regions. The report had some 234 authors, of which, notably, 28% were female, 41% were from developing countries, and 31% new to the IPCC process.

The five illustrative Scenarios used in this IPCC report

SSP: AR6 has used the concept of a ‘Shared Socioeconomic Pathway (SSP)’ in outcomes or models. SSPs are essentially scenarios based on how well or quickly humanity responds to climate change. They are designed to “span a range of challenges to climate change mitigation and adaptation”.

Working Group I considered nine new SSP emission and concentration scenarios covering a range of climate drivers and responses. However, for the final report, **a core set of five SSP scenarios** (Very low, Low, Intermediate, High, Very high) were selected.

¹ <https://www.ipcc.ch/assessment-report/ar6/>

Table 2: The five emission scenarios considered in the report

| Scenario | Global annual mean surface air temperature anomalies (°C) relative to 1850–1900 | | | Description |
|--------------------------------|---|-----------|-----------|--|
| | 2021–2040 | 2041–2060 | 2081–2100 | |
| Very low (SSP1-1.9) | 1.5°C | 1.7°C | 1.5°C | Warming to about 1.5°C above 1850-1900 in 2100 after slight overshoot and implied net zero CO ₂ emissions around mid-century. |
| Low (SSP1-2.6) | 1.6°C | 1.9°C | 2.0°C | Warming below 2.0°C relative to 1850-1900 with implied net zero emissions in the second half of the century |
| Intermediate (SSP2-4.5) | 1.6°C | 2.1°C | 2.9°C | With slight deviation from a 'no-additional climate-policy' reference scenario, the scenario is almost aligned with the upper end of aggregate NDC (climate pledge) emission levels by 2030, resulting in warming of about 2.7°C by 2100, relative to 1850-1900. |
| High (SSP3-7.0) | 1.6°C | 2.3°C | 3.9°C | A medium to high reference scenario with high non-CO ₂ emissions (including high aerosols) resulting from no additional climate policy under the SSP3 socioeconomic development pathway. |
| Very high (SSP5-8.5) | 1.7°C | 2.6°C | 4.8°C | A high reference scenario with no additional climate policy. Emission levels this high are not obtained by Integrated Assessment Models (IAMs) under any of the SSPs except the fossil fuelled SSP5 socioeconomic development pathway. |

Source: AR6 WG1 Report, IPCC

Twelve key findings from the IPCC's AR6 WG1

1. The human influence on the climate can now be better attributed

The effect of human activities on all parts of the climate system is much clearer now. **“Human-induced climate change is already affecting many weather and climate extremes in every region across the globe.”** For some observations such as increased concentrations of greenhouse gases in the atmosphere, it is *unequivocal*; for others it comes with *varying likelihoods*. One particular finding is that the human influence is compounding extreme events, which means that humans activities are causing different extreme events to happen at the same time or similar events to happen across different locations.

Human influence is also the main driver of the warming in the upper ocean (0-700m) (*extremely likely*) as well as the main driver of glacial retreat (*very likely*).

Figure 2: The human influence on various climatic events

| | Frequency | Intensity | Certainty | Confidence |
|---|-----------|-----------|-------------------|------------|
| Hot extremes | Higher | Higher | Virtually certain | High |
| Cold extremes | Lower | Lower | Virtually certain | High |
| Marine heatwave | Higher | / | Very likely | High |
| Heavy precipitation | Higher | Higher | Likely | High |
| Agricultural and ecological drought | Higher | Higher | / | Medium |
| Tropical cyclone (category 3 – 5) | Higher | Higher | Likely | Medium |
| Compound extreme events – concurrent heatwave and drought | Higher | / | Likely | High |

Source: IPCC, AR6 SPM

2. Atmospheric concentrations of GHGs are really high

In 2019, atmospheric concentrations were, on average, 410ppm (parts per million) for carbon dioxide (CO₂), which is the highest it has been in “at least 2 million years (*high confidence*)”. For methane (CH₄), 2019 saw 1,866ppb (parts per billion) and 332ppb for nitrous oxide (N₂O), which, with *very high confidence*, is the highest in at least 800,000 years.

These concentrations do not reflect the actual emissions into the atmosphere because the land and the oceans have been absorbing over half (56%) of CO₂ emissions since 1970 (*high confidence*). As cumulative emissions increase over time, the proportion absorbed by lands and oceans decreases, however, as modelled across the various scenarios.

3. Temperatures are rising 1.4-1.7x faster on land than oceans

The temperature of the earth’s surface was around 1.09°C (in a range of 0.95-1.2°C) higher in the decade 2011-20 than the 1850-1900 period. However, the warming was partly masked by aerosols, which caused cooling in the range of 0.0-0.8°C. The **“Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (high confidence).”**

All emissions scenarios find that the **“global surface temperature will continue to increase until at least the mid-century”** and that the Paris Agreement goals of limiting temperature rises to 1.5°C and 2°C will be exceeded this century **“unless deep reductions in CO₂ and other greenhouse gas emissions occur in the coming decades.”** Figure 3 shows the best estimate of temperature increases under each scenario.

Figure 3: Best estimate of temperature increases under each scenario.

| | Near term, 2021–2040 | Mid-term, 2041–2060 | Long term, 2081–2100 |
|-----------------------|----------------------|---------------------|----------------------|
| GHG emission Scenario | Best estimate (°C) | Best estimate (°C) | Best estimate (°C) |
| Very low | 1.5 | 1.6 | 1.4 |
| Low | 1.5 | 1.7 | 1.8 |
| Intermediate | 1.5 | 2 | 2.7 |
| High | 1.5 | 2.1 | 3.6 |
| Very high | 1.6 | 2.4 | 4.4 |

Source: IPCC, AR6 SPM. Best estimate refers to the most likely value.

4. Precipitation will become more frequent and more intensive

The rate of increase in globally averaged precipitation is increasing in general across most regions, with their frequency and intensity rising with the temperature. The warmer it gets, the heavier the precipitation will be (*very likely*) as there is *high confidence* that **“extreme daily precipitation events are projected to intensify by about 7% for each 1°C of global warming”**.

The IPCC finds that warming will also increase the variation in rainfall that is associated with the El Niño–Southern Oscillation (i.e. El Niño and La Niña) in the Intermediate to Very high scenarios.

5. Sea levels are rising faster than before

Sea levels have increased globally by around 20cm (in a range of 15-25cm) since the beginning of the 20th Century. However, they are rising faster than any of the preceding centuries in the last 3000 years (*high confidence*). Half of the rise in sea levels is attributed to thermal expansion, 42% from glacial and ice sheet loss, and 8% from changes in land water storage.

6. Climate sensitivity is “near-linear”

The IPCC finds that if atmospheric concentrations of CO₂ were to double from pre-industrial times, then the steady state (equilibrium) for the surface temperature would *likely* be between 2.5°C and 4°C (*high confidence*), with a “best estimate” of 3°C.

The response of the climate to increases in CO₂ is “near-linear”, with 1000 GtCO₂ of cumulative CO₂ emissions estimated to increase global surface temperatures by 0.45°C (in a range of 0.27-0.63°C). On our calculations, this equates to just under 0.5°C of warming for every 20 years of GHGs emissions at the current annual global run rate.

7. Warming increases the frequency and intensity of extreme events

The IPCC finds that warmer temperatures increase both the frequency and intensity of various extreme events – and that this effect becomes larger “with every additional increment of global warming” (Figure 4).

Figure 4: The effect of warmer temperatures on extreme events

| | Present | | Future | |
|-------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1°C | 1.5°C | 2°C | 4°C |
| Hot extremes (10-year event) | 2.8 times, +1.2°C | 4.1 times, +1.9°C | 5.6 times, +2.6°C | 9.4 times, +5.1°C |
| Hot extremes (50-year event) | 4.8 times, +1.2°C | 8.6 times, +2.0°C | 13.9 times, +2.7°C | 39.2 times, +5.3°C |
| Heavy precipitation (10-year event) | 1.3 times, +6.7% wetter | 1.5 times, +10.5% wetter | 1.7 times, +14.0% wetter | 2.7 times, +30.2% wetter |
| AGR/ECOL drought (10-year event) | 1.7 times, +0.3 sd drier | 2.0 times, +0.5 sd drier | 2.4 times, +0.6 sd drier | 4.1 times, +1.0 sd drier |

Source: IPCC, AR6 SPM. Note: AGR/ECL refers to "agricultural" or "ecological" drought which depends on the "affected biome".

8. Carbon sinks only work to a certain extent

The concept of carbon dioxide removal (CDR) is elaborated in the IPCC report. Although CO₂ can indeed be removed and stored, its effects are mixed. For example, CDR would gradually reverse temperature increases on land. However, not all climatic effects would be reversed. Some effects may take decades to millennia to be reversed (*high confidence*); sea level declines would take "several centuries to millennia" (*high confidence*).

“ 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
IPCC, AR6 SPM (B.5)

9. Tipping points are irreversible changes over centennial or millennial time scales

There are further descriptions of how climatic changes cannot be reversed in short time frames. For example, the effects on the oceans – surface temperatures, acidification, and deoxygenation – with *medium to very high confidence* levels; sea-level rises and ice sheet melt (*high confidence*), and permafrost may not reform for hundreds of years (*high confidence*).

10. Highly disruptive events “cannot be ruled out”

The report also described some events that have a *low-likelihood* of occurrence, but the effects of which would be catastrophic. These events, such as the collapse of ice sheets or abrupt changes to ocean circulation, form part of the risk assessment and “cannot be ruled out”.

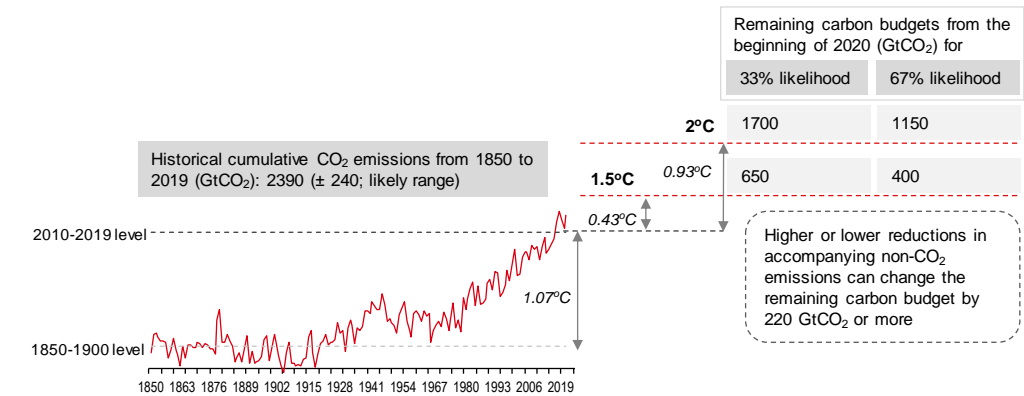
“The Atlantic Meridional Overturning Circulation is very likely to weaken over the 21st century for all emission scenarios” (*high confidence*), but with *low confidence* in the magnitude. There is only *medium confidence* that such a collapse will not occur before 2100. The effects would be highly disruptive to weather patterns and the water cycle.

“ Abrupt responses and tipping points of the climate system, such as strongly increased Antarctic ice sheet melt and forest dieback, cannot be ruled out
IPCC, AR6 SPM (C.3.2)

11. The carbon budget is running out

The carbon budget is an estimation of how much CO₂ can be emitted yet staying within a reasonable chance of limiting warming to specific temperature increases. Some 2,390 GtCO₂ was emitted in the years 1850–2019. The figure below shows that only 400 more GtCO₂ can be emitted from 2020 onwards in order to have a two-thirds chance of limiting warming to 1.5°C; this roughly equates to 8 years of 2019 GHG emission levels.

Figure 5: The carbon budget continues to be depleted



Source: IPCC, AR6 SPM

12. Regional effects are a lot more nuanced

This sixth assessment incorporated a lot more details of how climate impacts would affect various regions. This would have various implications for economic and business planning in the affected regions.

Figure 6: The impacts of climate change will affect all regions

| Summary of projected regional change | | |
|--------------------------------------|---|--|
| All regions | <ul style="list-style-type: none"> (+) hot climatic impact-drivers (CID) (-) cold climatic impact drivers (-) permafrost, snow, glaciers, ice sheets, lake and sea ice | |
| North and Central America | 1.5C scenario | 2C and above |
| | <ul style="list-style-type: none"> (+) precipitation and flooding (+) AGR/ECOL drought | <ul style="list-style-type: none"> (++) precipitation and flooding (+) AGR/ECOL and HYDR drought |
| Central and South America | 1.5C scenario | 2C and above |
| | <ul style="list-style-type: none"> (+) AGR/ECOL drought | <ul style="list-style-type: none"> (+) AGR/ECOL drought |
| Europe | 1.5C scenario | 2C and above |
| | <ul style="list-style-type: none"> (+) precipitation and flooding (+) AGR/ECOL drought | <ul style="list-style-type: none"> (++) precipitation and flooding (+) AGR/ECOL and HYDR drought |
| Africa | 1.5C scenario | 2C and above |
| | <ul style="list-style-type: none"> (+) precipitation and flooding (+) AGR/ECOL drought | <ul style="list-style-type: none"> (+) AGR/ECOL and HYDR drought |
| Asia | 1.5C global warming | 2C and above |
| | <ul style="list-style-type: none"> (+) precipitation and flooding | <ul style="list-style-type: none"> (+) precipitation and flooding |
| Australasia | 1.5C global warming | 2C and above |
| | <ul style="list-style-type: none"> (+) AGR/ECOL drought | <ul style="list-style-type: none"> (+) AGR/ECOL and HYDR drought |

Source: IPCC, AR6 SPM

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Issuer of report

The Hongkong and Shanghai Banking Corporation Limited
Level 19, 1 Queen's Road Central
Hong Kong SAR
Telephone: +852 2843 9111
Fax: +852 2801 4138
Website: www.research.hsbc.com

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