SCIENCE OF CLIMATE CHANGE 2020

Present and future

IBERDROLA

What you will find in this document:

- A compilation of scientific information of reference to give an overview of climate change and its implications.
- Evidence on current and anticipated future changes (projections).

The main reports from the authoritative bodies on the subject have been considered, particularly those prepared by the UN Intergovernmental Panel on Climate Change (IPCC).

Content

EXECUTIVE SUMMARY

1. Human influence on the climate system is clear

The anthropogenic emission of greenhouse gases (GHGs) that accumulate in the atmosphere and retain heat is increasing what is known as the "greenhouse effect" and contributing to an increase in global temperatures. This effect could last for many millennia before natural processes remove these gases from the atmosphere.

- The **atmospheric CO_2 concentration reached its maximum annual average of 409.8 parts per million in 2019**, which is higher than the levels observed in at least the last 800,000 years and higher than any concentration levels that humans have ever lived with* . Carbon dioxide is important because it is the GHG that contributes most (over two thirds) to global warming. The fifth Assessment Report (AR5) of the UN Intergovernmental Panel on Climate Change (IPCC) concluded with a high level of confidence that human influence through GHG emissions has been the dominant cause of warming observed since the mid-twentieth century. In fact, since the late 1950s, CO_2 has increased by almost 100 ppm, almost 5 times faster than in the first half of the observation record (~20 ppm)** .
- **The IPCC has stated that the objectives of** the Paris Agreement involve not exceeding **an atmospheric CO_2 concentration of 450 ppm CO_2-eq. (to limit temperature rise to 2°C) or 430 ppm CO_2-eq (to 1.5°C) by the end of the century**.

* Blunden, J. and D. S. Arndt, Eds., 2020: State of the Climate in 2019. Special Online Supplement to the Bulletin of the American Meteorological Society
** NOAA, R. Lindsey, [12 February 2020]

- **The increase in CO_2 concentration is mostly due to** emissions from burning fossil fuels, which are the main source of total greenhouse gas emissions expressed as carbon-equivalent (~55.3 $GtCO_2e$ in 2018) (UNEP 2019). Between 2009-2018, CO_2 emissions averaged about 34.7 ± 1.8 $GtCO_2$ per year, growing at an average annual rate of 0.9% to reach a record 36.6 $GtCO_2$ in 2018 (WMO, 2020).

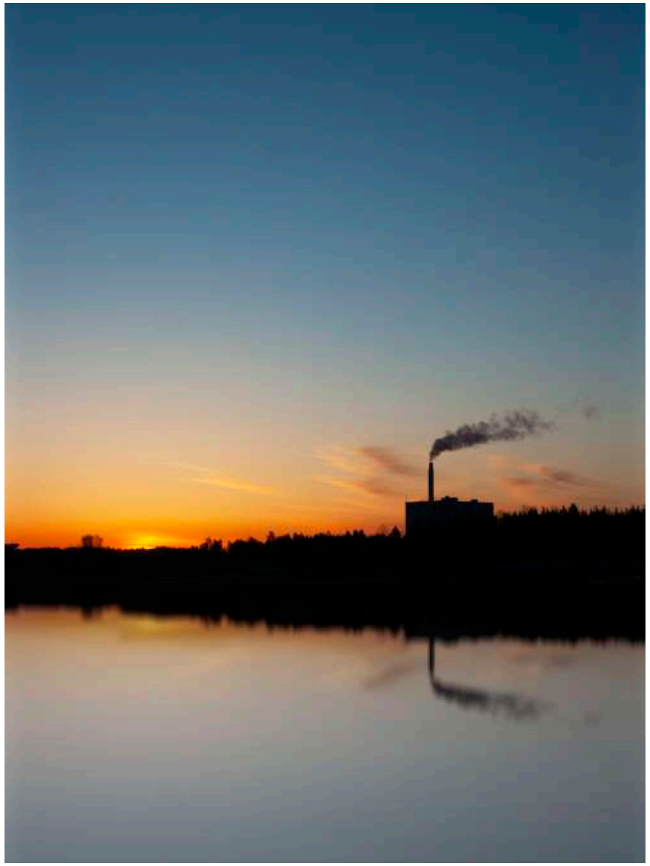
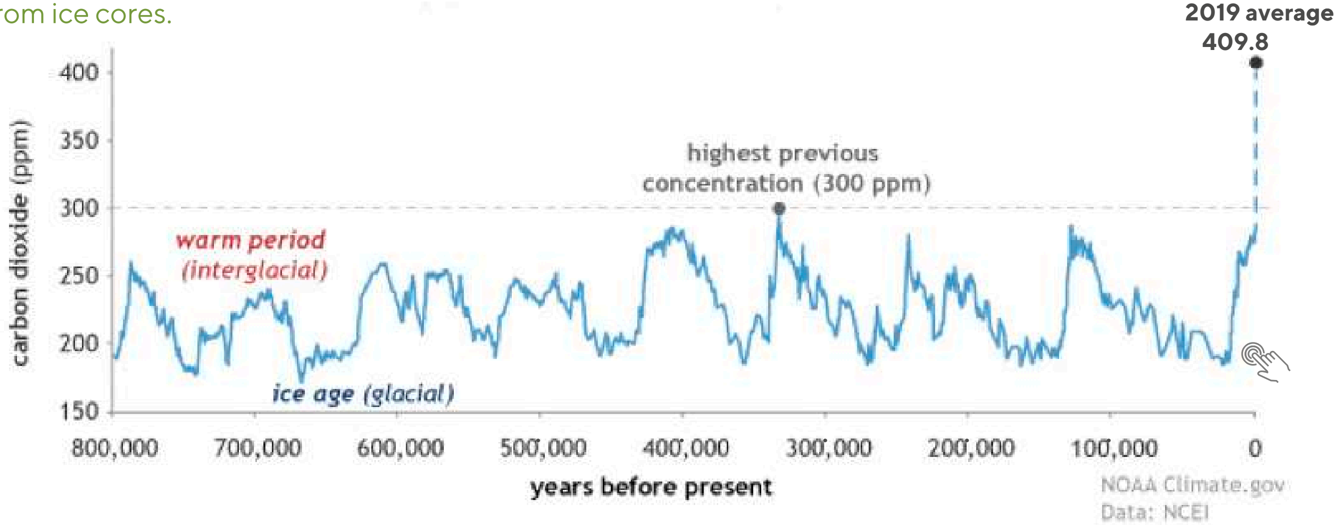


Figure 1: Trend indicators for greenhouse gas emissions and atmospheric concentration

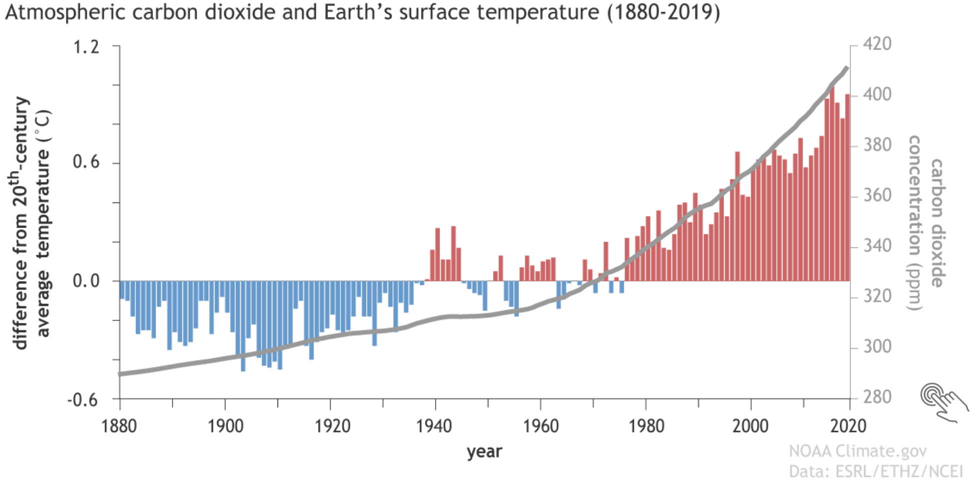
Evolution of atmospheric CO_2 concentration (NOAA, R. Lindsey, August 2020)

CO_2 concentration during ice ages and warm periods for the last 800,000 years has been reconstructed from ice cores.



Evolution of CO_2 concentration and temperature (NOAA, R.Lindsey, February 2020)

The increase in CO_2 concentration (line) coincides with the increase in temperatures (bars)



2. Scientific evidence shows that climate change is a reality

Scientific data show that its effects are occurring at an unprecedented rate and that it is having observable consequences:

- **Global temperatures have been rising steadily since 1880**, with 19 of the hottest 20 years since records began having occurred since 2001. **2019 was the second warmest year on record**, with an average global surface temperature that exceeded that of the pre-industrial era (1850-1900) by ~1.1°C, with a greater increase over land than over the ocean. Since the 1980s, each successive decade has been warmer than every previous one, with continuous warming in the range of 0.1°C to 0.3°C per decade (WMO, 2020).
- **The consequences of this global warming are being seen in other variables:**
  - The ocean is breaking warming records, with the **frequency of marine heat waves having doubled since 1982** (IPPC, 2019b). Marine heat waves occurred in ~84% of ocean waters in 2019 (WMO, 2020).
  - This ocean warming is contributing to an **observed reduction in the ocean oxygen inventory by 1-2%** since 1950. In addition, the oceans absorb 23% of annual CO_2 emissions resulting in an increase in their acidity by around 26% since the late 1980s (WMO, 2020).
  - **The melting of continental ice masses, sea ice and glaciers is accelerating**. According to the IPCC (2019b) the loss of mass in the polar ice sheets during the period 2007-2016 tripled in Antarctica and doubled in Greenland from 1997-2006.
  - In **2019, the average sea level reached its highest value** since high-precision satellite records were available (January 1993) with an estimated rate of increase of 3.24[1] ± 0.3 mm/year.
- There is **also a relationship between global warming and extreme weather events (heatwaves, cyclones, etc.)**. Despite the complexity of their study, since they are by definition rare/exceptional, there is a general consensus that changes in the frequency or intensity of these events are increasing in many regions as a result of global climate change.

1. While 3 mm may not seem much, it equates to nearly 42 trillion cubic metres of water (NASA/JPL-Caltech, 2020, Rising Tides: Understanding Sea Level Rise)

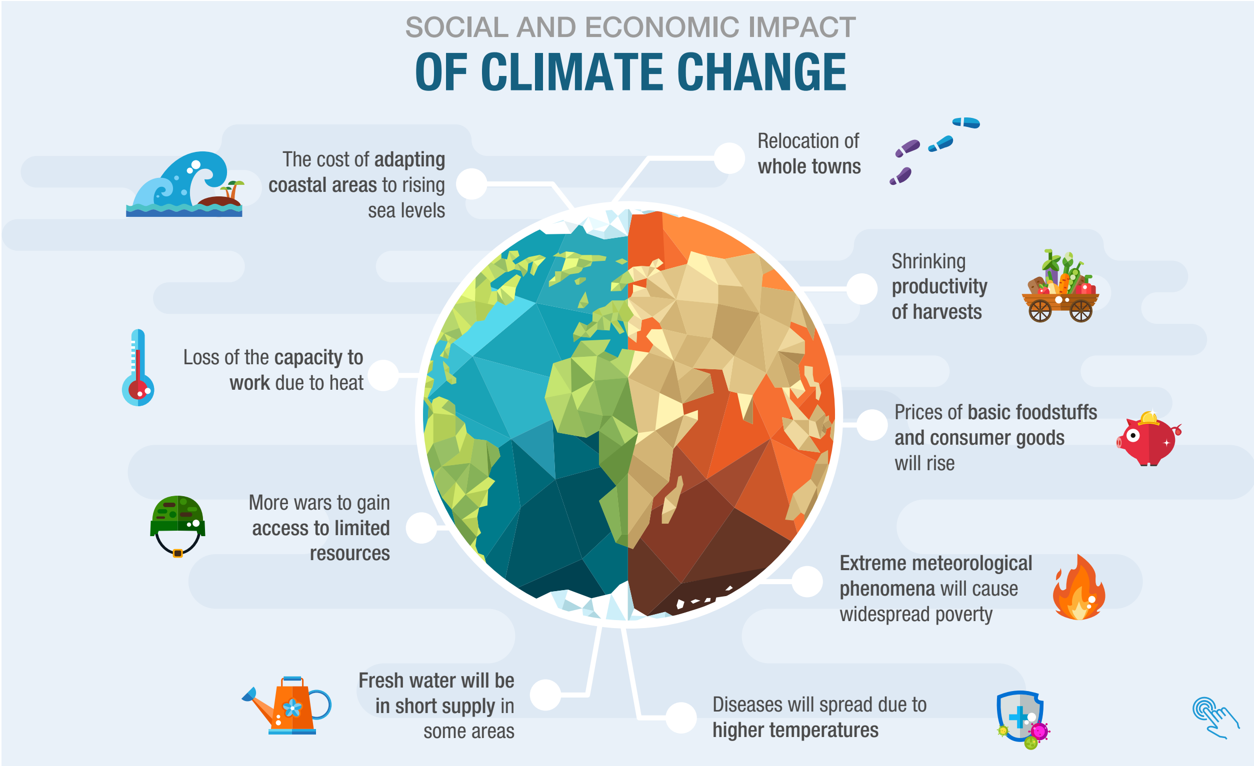
19 of the hottest 20 years since records began have occurred since 2001

3. Climate change, particularly extreme events, is greatly affecting human well-being and all sectors of activity

Its influences are felt both directly and indirectly through its impacts on natural and socio-economic systems:

- It is **one of the three major direct drivers of biodiversity loss**, thus endangering the many goods and services biodiversity provides us. It has negatively affected 47% of endangered terrestrial mammals, excluding bats, and 23% of endangered birds in at least part of their distribution (IPBES, 2019).
- In 2018, the World Health Organization (WHO) **defined climate change as the greatest health challenge of the twenty-first century**, as it threatens all aspects of our current society and, by a conservative estimate, will cause approximately 250,000 additional deaths per year between 2030 and 2050.
- It has **important implications for the quality of natural resources that are key to food supply**, as crops and livestock have physiological limits including those related to temperature. According to the World Meteorological Organization (WMO, 2020), climate variability and extreme weather events are among the main drivers of the recent increase in world hunger. On average, world average yields of rice, maize and wheat are expected to decline by 3% to 10% per degree of warming above historical levels[2].

Figure 2: Socio-economic effects of climate change



- **Climate change is also considered one of the greatest threats to economic stability**. Natural disasters caused overall losses of nearly $5 billion between 1980-2018, with more than 80% of this total events caused by climate-related events **.

2. European Commission, 2020, Factsheet, The business case for biodiversity.

** Munich Re, NatCatSERVICE (2020). Relevant natural loss events worldwide 1980 – 2018

4. A certain degree of climate change is inevitable, and this will require adaptation action

- The **future climate** will depend on the warming from past anthropogenic GHG emissions as well as future emissions and natural climate variability (IPPC, AR5, 2014). To estimate possible future climate features, the IPCC has defined a series of representative concentration pathways (RCPs), which are used to make projections that simulate climate changes during the twenty-first century.
- These projections show that, in the short term, the physical effects of climate change are similar for all scenarios, due to the effect of accumulated emissions, the inertia of the climate system and current emission levels, with the Paris Agreement limit of 1.5°C expected to be reached around 2040, if current warming rates are maintained.
- The great variation in the predicted physical results arises after 2050, depending on the actions taken in the coming decades, so that, if global climate neutrality is achieved by 2050, the increase in global temperature could remain at 1.5°C in 2100.
- However, the stabilisation of the global average surface temperature does not imply the stabilisation of all aspects of the climate system, and some aspects, such as sea level rise, will continue for centuries as they respond more slowly to changes in global temperature.

The Paris Agreement limit of 1.5°C is expected to be reached around 2040, if current warming rates are maintained.

5. Mitigation action is key: every tenth of a degree of temperature rise avoided is important

This requires reducing emissions by 45% by 2030 compared to 2010 and achieving net zero emissions by 2050.


Wind Park Mel II (RN)

- **The impacts increase rapidly**, even exponentially, depending on the emission scenarios that influence the change in temperature. The more the climate is disturbed, the greater the risk of severe, widespread and irreversible impacts on ecological and human systems.
- The IPPC (SR15, 2018) warns of the risks posed by an increase of 1.5°C at the end of the century, even compared to a 2°C scenario. **Limiting the temperature increase to 1.5°C by 2100 is still possible** and would substantially reduce the magnitude of many impacts. This requires reducing emissions by 45% by 2030 compared to 2010 and achieving net zero emissions by 2050.

Figure 3: Comparison between some expected impacts in 2100 for various scenarios (CRO Forum/IPCC, 2019)

Warming by 2010

		<2 °C		3 °C	5 °C
Physical impacts		1.5 °C	2 °C		
Sea-Level Rise (cm)		0.3-0.6 m	0.4-0.8 m	0.4-0.9 m	0.5-1.7 m
Coastal assets to defend ($tn)		$10.2tn	$11.7tn	$14.6tn	$27.5tn
Chance of ice-free Arctic summer		1 in 30	1 in 6	4 in 6 (63%)	6 in 6 (100%)
Tropical cyclones:	Fewer (#cat 1-5)	-1%	-6%	-16%	Unknown
	Stronger (# cat 4-5)	+24%	+16%	+28%	+55%
	Wetter (total rain)	+6%	+12%	+18%	+35%
Frequency of extreme rainfall		+17%	+36%	+70%	+150%
Increase in wildfire extent		x1.4	x1.6	x2.0	x2.6
People facing extreme heatwaves		x22	x27	x80	x300
Land area hospitable to malaria		+12%	+18%	+29%	+46%

6. Climate action will have a profound impact on the global climate

In the image, from left to right, the president of Iberdrola, Ignacio Sánchez Galán, Mary Robinson (president of the NGO The Elders) and António Guterres (Secretary General of the United Nations) in the Climate Summit COP25 (2019).

- Global efforts to reduce emissions in the coming decades will have a profound impact on the global climate in the second half of this century. These **mitigation efforts will need to be accompanied by actions to adapt** to the changing conditions to address the challenge.

Mitigation efforts will need to be accompanied by actions to adapt

Opening ceremony of the fortieth session of the IPCC, Denmark, 2014
source: @IPCC

1 INTRODUCTION

This document **collates background scientific information to provide an overview** of climate change. Through analysis of the trends in a number of indicators, evidence is provided on current and future changes (projections). The aim is to strengthen understanding of this global problem and its implications, while providing up-to-date data and information that may be useful in addressing its main risks.

Taking into account the constant evolution of science and the emergence of new projection data on climate variables, this is a **living document** that will be updated regularly in accordance with the available information. In its preparation, the main references have been the **reports from the international organisations that are an authority and current reference on the subject**, as shown in the table below.

Table 1. Main information sources on climate change science

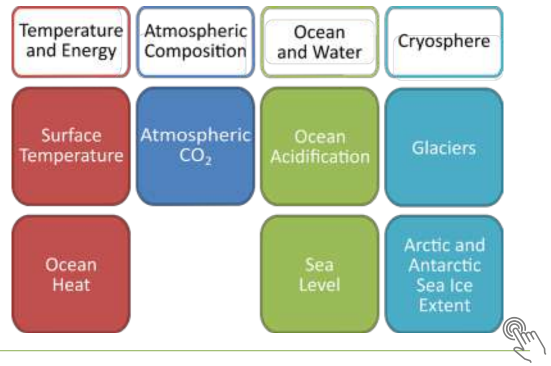
Authority	Description
Intergovernmental Panel on Climate Change (IPCC)	Main international body for assessing the current state of knowledge on climate change. It was created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988. It evaluates peer-reviewed literature every five to six years, and publishes its findings on the past, present and future climate in Assessment Reports, which are in turn subject to an intensive review process involving hundreds of scientific experts and government reviewers worldwide. Currently 195 countries are members of the IPCC and their governments participate in the review process and in plenary sessions, where the reports are adopted and approved. It is one of the most analysed documents in the history of science. The fifth IPCC Assessment Report (AR5) was published between 2013-2014 and it is currently in the process of drafting its sixth report, which is to be published between 2021-2022. In addition, the IPPC publishes special reports focusing on a specific topic, including the following: • Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2013) (SREX, 2012) • Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels (2018) (SR15, 2018) • Special Report on Climate Change and Land (SRCCL, 2019) • Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC, 2019)
World Meteorological Organization (WMO)	It monitors the Earth's climate on a global scale and coordinates research on the subject, through the *Global Climate Observing System (GCOS) programme*. In March each year, it publishes a **Statement on the State of the Global Climate**, based on data provided by the National Meteorological and Hydrological Services and other organisations. It is presented to the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). This declaration is based on the monitoring of a set of global climate indicators, based on 7 main parameters, which are complemented by a set of subsidiary indicators. 

Table 1. Main information sources on climate change science

Authority	Description
Europe	The European Commission monitors climate at the global and European level through the Copernicus Climate Change Service (C3s), which makes reliable information about the climate situation available to society. It publishes monthly and annual newsletters on the state of the European climate based on in situ and satellite observations and climate models. This is based on data provided by National Meteorological Services such as the Met Office in the United Kingdom and the Spanish Meteorological agency (AEMET).
United States	The United States Global Change Research Program (USGCRP) coordinates and integrates research by 13 federal agencies on changes in the global climate and environment and their implications for society. It regularly prepares the **National Climate Assessment** (NCA), the latest version of which is from 2018 (similar to IPCC reports). The NASA Space Agency and the National Oceanic and Atmospheric Administration (NOAA) also play an important role in the field of climate science, producing monthly and annual bulletins on the state of the climate globally and in the US.

"The samples that scientists collect from the ice, called ice cores, have a record of what our planet looked like hundreds of thousands of years ago. The oldest, from East Antarctica, provide an 800,000-year record of the Earth's climate. Ice core logs are an essential part of validating climate models that predict Earth's future climate." *

* Source "NASA's Jet Propulsion Laboratory"
https://climate.nasa.gov/news/2616/core-questions-an-introduction-to-ice-cores

2 BASIC CONCEPTS

2.1 What is climate change?

The climate[3] is the set of long-term atmospheric conditions that has always been subject to variations as a result of different natural phenomena (volcanic eruptions, solar radiation, etc.). However, a climate alteration has been occurring at an unprecedented rate for several decades.

The scientific evidence points to human action as being responsible for this acceleration, as a result of the generation of greenhouse gas (GHG) emissions that accumulate in the atmosphere and trap heat, increasing what is known as the greenhouse effect, and contributing to a rise in global temperatures. **This alteration due to anthropogenic actions is what is known as "climate change"**.

This term is often replaced by "global warming", as this is the main way in which humans are affecting the climate.

Article 1 of the **United Nations Framework Convention on Climate Change (UNFCCC)** defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

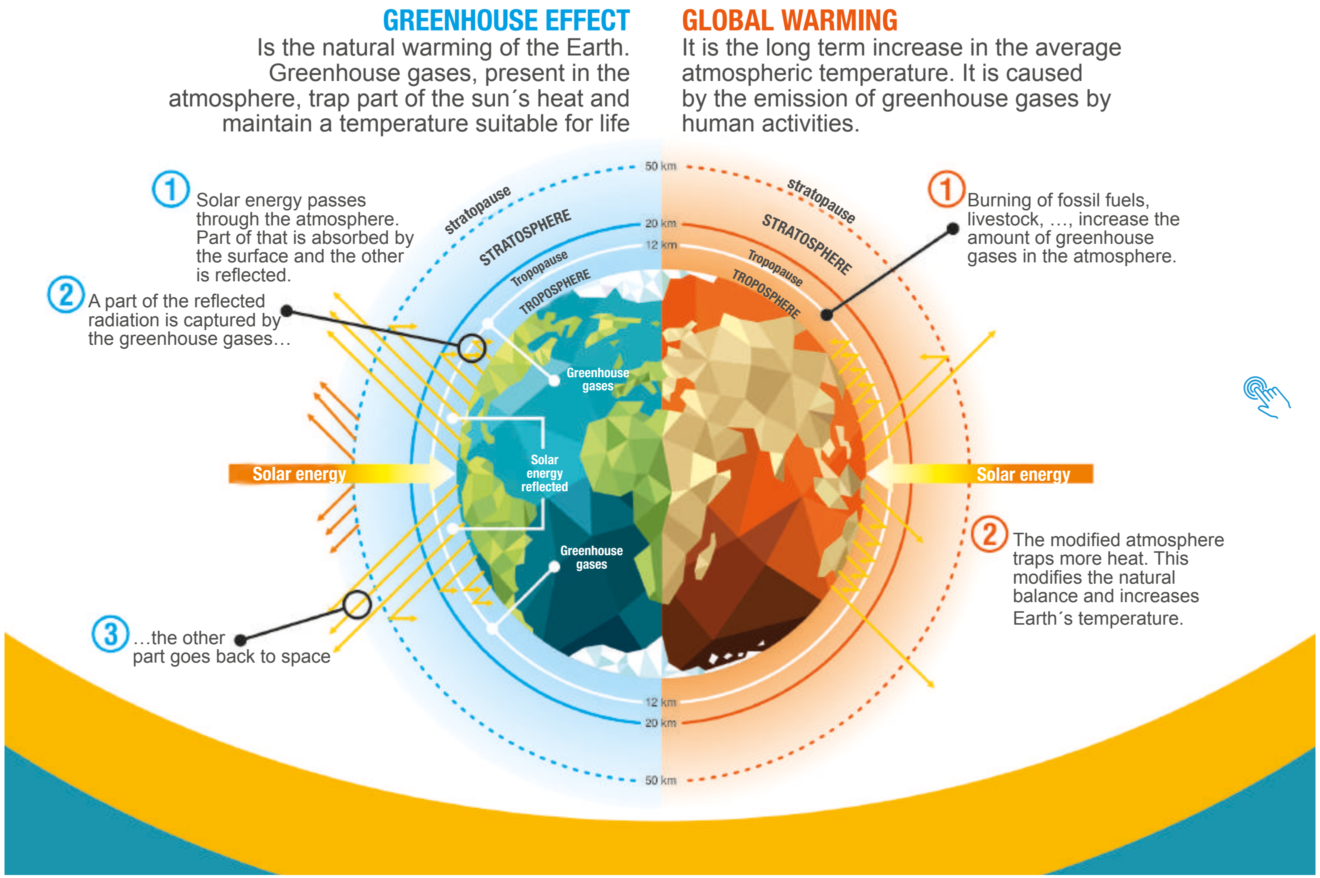
3. The climate is strictly defined as a statistical description of atmospheric weather in terms of mean values and the variability of the corresponding magnitudes (e.g. temperature, precipitation or wind) over periods ranging from months to millions of years. The usual average period is 30 years, according to the WMO. In a broader sense, climate is the state of the climate system, which consists of five main components: atmosphere, hydrosphere, cryosphere, lithosphere and biosphere, and the interactions between them. The climate system evolves over time under the influence of its own internal dynamics and due to the effect of external forces, such as volcanic eruptions or solar variations, and anthropogenic forces, such as changing atmospheric composition or changing land use.

2.2 Greenhouse gases

The term "greenhouse effect" refers to the retention of the Sun's heat on the Earth by a layer of gases in the atmosphere. Without these gases life as we know it would not be possible, as the planet would be too cold (it would be about 30°C cooler). Most greenhouse gases are generated naturally and include water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3). However, industrialisation has meant that the emission and concentration of these gases has increased exponentially since the beginning of the last century, whereas, without human action, nature would have balanced the natural emissions of these gases. By increasing these gases, we are changing the balance (called "radiative forcing") between the amount of energy entering and exiting the atmosphere, and as a result the amount of infrared radiation accumulated by the Earth is increasing. This leads to an increase in the temperature across the entire planet.

Carbon dioxide is the gas we produce the most and is responsible for most of the warming (due to the large volume of emissions and its long permanence in the atmosphere), although other GHGs that we emit less are also important, as they can absorb more heat per molecule (warming potential). These include **methane, nitrous oxide and a number of fluorinated and synthetic gases** described in the table below. In addition, we emit other substances that also act as short-lived climate forcers, including a number of precursor gases that, when in the atmosphere, form substances that contribute to the greenhouse effect (such as ground-level ozone (O_3)), as well as aerosols such as black carbon, which can have a cooling or warming effect.

Figure 4: Illustration showing the greenhouse effect



Source: Spanish Committee of the International Union for the Conservation of Nature (IUCN)

4. Usually measured in watts per square metre (W/m^2)

5. These gases with an indirect effect include, but are not limited to, carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO_x), ammonia (NH_3) and sulphur dioxide (SO_2).

Table 2. Greenhouse gases

Gas	Main sources	Global warming potential (GWP) (over 100 years) compared to CO_2 (heat absorbed per molecule)	Permanence in the atmosphere	Global contribution to GHG warming between 2018 and the pre-industrial era[6]
Carbon dioxide (CO_2)	• Burning of fossil fuels • Deforestation and land-use changes	–	Between 50 and 200 years	66%
Methane (CH_4)	• In agriculture, e.g. from the digestive system of cattle and from rice crops • Waste decomposition • Extraction and transportation of natural gas, oil and coal	28 times more than the same amount of CO_2	Between 10 and 15 years	17%
Nitrous oxide (N_2O)	• Soil fertilisation • Industrial processes	About 265 times more than the same amount of CO_2	Around 114 years	6%
Fluorinated and other synthetic gasess[7]	• Artificially created for industrial and refrigeration applications	Depending on the gas, from 100 to 23,000 times more than the same amount of CO_2	Depending on the gas, a few thousand years	11%[7]

6. WMO Greenhouse Gas Bulletin (2019) and EEA (2019) "Atmospheric greenhouse gas concentrations". Refers to the contribution of each long-lived GHG, including methane, to the change in the planet's energy balance (called "radiative forcing"). The contribution by all the GHGs is estimated at 3.1 W/m2 since the pre-industrial era. The contribution of each gas to climate change is determined by its volume of emissions, its permanence in the atmosphere and its global warming potential.

7 Fluorinated gases (hydrofluorocarbons -HFCS-, perfluorocarbons -PFC- and sulphur hexafluoride -SF6) have been used in many industrial and refrigeration applications as substitutes for ozone-depleting substances (ODS) since they do not affect the ozone layer. However, like ODS (e.g. chlorofluorocarbons -CFCs), they have a high warming potential, and a long duration in the atmosphere, so they contribute to climate change, although due to their low emissions their contribution to radiative forcing is low (<2%). Therefore they were also included in the Kyoto Protocol on Climate Change, while ODS are regulated by the Montreal Protocol, even if they also contribute to climate change and have been responsible for 8-9% of the radiative forcing caused by long-lived GHGs between the pre-industrial period and 2018.

3 EVIDENCE OF CLIMATE CHANGE

> "Climate change is the defining challenge of our time"

Antonio Guterres,
UN Secretary General
WMO Statement on the State of the Global Climate, 2019

Climate change is **global, it is occurring at an unprecedented rate and will have long-term effects, which are already a reality**. As UN Secretary General, António Guterres, warns, "climate change is the defining challenge of our time". He also warns (March, 2017) that it represents an unprecedented threat to peace, prosperity and the Sustainable Development Goals: " **We are dealing with scientific facts, not politics. And the facts are clear**.

Major scientific reports confirm how the rise in global temperature is related to other changes in the climate system. The fifth IPCC Assessment Report (AR5, 2013) found that "*Warming of the climate system is unequivocal. Since the 1950s many of the observed changes are unprecedented over decades to millennia. The concentrations of greenhouse gases have increased, the atmosphere and ocean have warmed, the amounts of snow and ice have diminished, the Arctic summer sea ice is retreating and sea level has risen*". These observations, which are endorsed by the most recent published reports on the current state of the climate by the main bodies (see Table 1), show how all the indicators have seen an acceleration in climate change, with 2019 and the first months of 2020 once again breaking several records. The results from the monitoring of these indicators are presented below.

3.1 We are affecting the composition of the atmosphere through our emissions

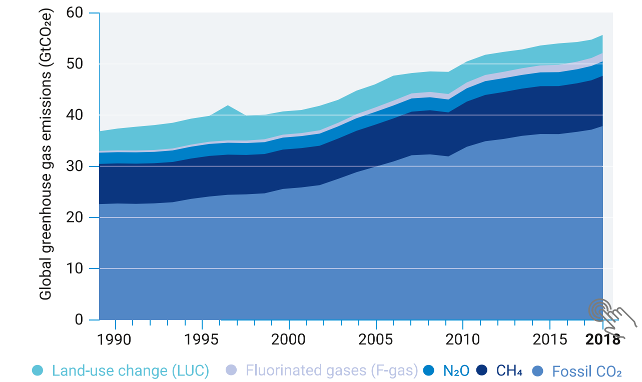
The increase in greenhouse gas (GHG) concentrations in the atmosphere reflects the balance between their sources (natural and anthropogenic) and their sinks (which remove them from the atmosphere). Figure 5(a) shows the continued increase in anthropogenic emissions of these gases for the period 1990-2018. CO2 emissions account for more than three quarters of total emissions, followed by methane (19%) and nitrous oxide (6%)[8]. Between 2009-2018 GHG emissions, including land-use changes, have increased at a rate of 1.3% annually, **reaching a record ~55.3 GtCO2e in 2018 (UNEP, 2019)**, an increase of 2% over the previous year. Current GHG emissions, excluding those from land-use change, are approximately 57% higher than in 1990 and 43% higher than in 2000 (PBL, 2020).

CO_2 emissions from burning fossil fuels dominate total emissions and contribute most to warming. Between 2009-2018, they averaged about 34.7 ± 1.8 $GtCO_2$ per year, growing at an average annual rate of 0.9% to reach a record 36.6 GtCO2 in 2018 (+2% compared to 2017). For its part, the use and change of land use due to human activity (deforestation, fires, etc.) in that period released about 5.5 ± 2.6 $GtCO_2$ stored in ecosystems (~14% of anthropogenic CO_2) (WMO, 2020). Of all these emissions, about 45% have been absorbed by the oceans and the terrestrial biosphere, which act as sinks and natural carbon stores, contributing to a reduction in atmospheric concentration. But these have a limited capacity and their deterioration is destroying natural absorption sources. The result is that the concentration of atmospheric GHGs is increasing, on the one hand, due to the higher level of emissions and, on the other, due to the lower capacity of the sinks (Figure 5b).

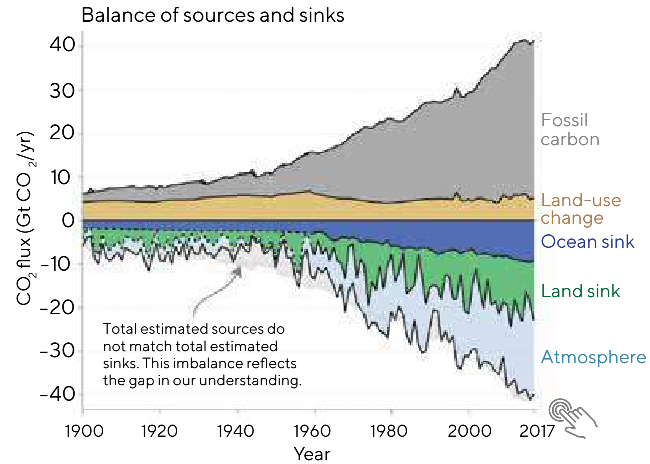
8. Trends in global CO_2 and total greenhouse gas emissions: 2019 Report. PBL Netherlands Environmental Assessment Agency, 2020. This figure refers to the total volume of anthropogenic emissions. It is different from the percentages shown in Table 2, which refer to the contribution by the atmospheric concentration of each gas in the atmosphere to the total radiative forcing (warming) of all GHGs, estimated at 3.1 W/m2 since the pre-industrial era.

Figure 5: Trend indicators for greenhouse gas emissions

a) GHG emissions by type 1990-2012 (UNEP, 2019)



b) Balance between CO_2 emission sources and sinks between 1900 – 2017 (WMO, 2019)



For its part, emissions of methane (CH_4), the next most important GHG, grew at 1.3% per year in the last decade and 1.7% in 2018. Nitrous oxide (N_2O) emissions have been growing steadily, at 1% annually over the last decade and 0.8% in 2018. Fluorinated gas emissions (SF_6, HFCs, PFCs) are growing faster, at 4.6% annually in the last decade and 6.1% in 2018 (UNEP, 2019).

As a result, **GHG concentrations in the atmosphere continue to trend upwards** with new highs in 2018, with CO_2, CH_4 and N_2O values accounting for 147%, 259% and 123% of pre-industrial levels (before 1750), respectively (WMO, 2020).

In terms of CO_2 equivalent, the atmosphere contained ~500 ppm in 2019, of which more than 80% is CO_2 alone (NOAA[9]).

Specifically, the CO_2 concentration reached its maximum annual average of 409.8 parts per million in 2019, higher than the levels observed over, at least, the last 800,000 years (these historic concentrations have been reconstructed from ice cores).

Peak and depression cycles in CO_2 concentrations track glaciation (lower CO_2) and warmer interglacial periods (higher CO_2) and never exceeded 300 ppm.

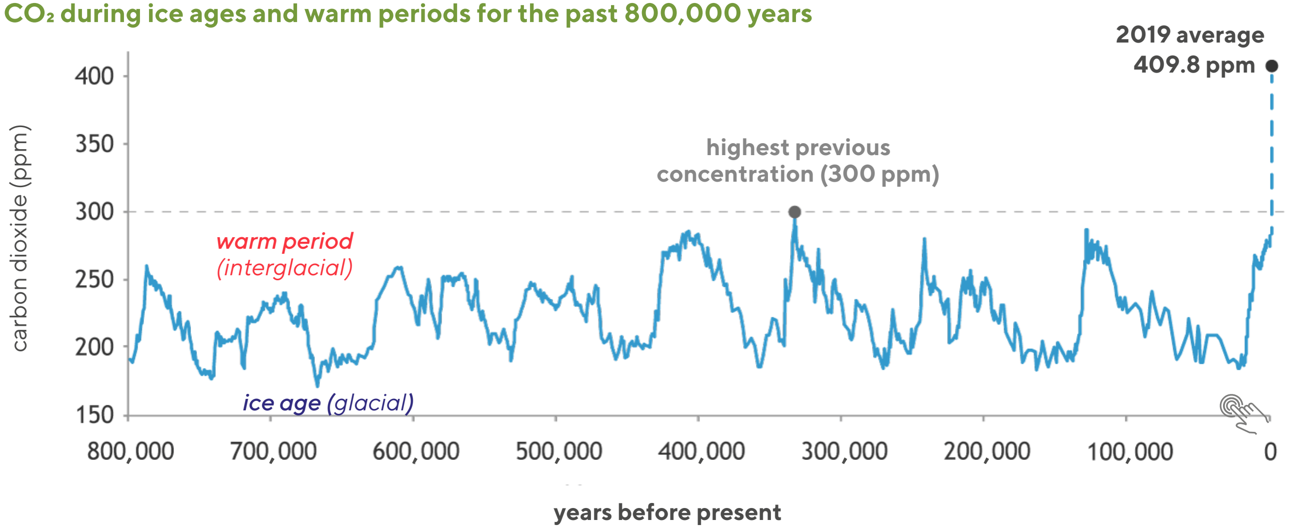
We have now exceeded the 400 ppm threshold, which is considered to be its highest level in at least the last three million years[10], and the concentration is rising faster than it has done in hundreds of thousands of years, and it is now approximately 26% higher than in 1970.[11]

Due to the long period that GHGs remain in the atmosphere (*Table 2*), after we stopped emitting them it would be hundreds of years before natural processes remove them from the atmosphere.

We have now exceeded the 400 ppm threshold, which is considered to be its highest level in at least the last three million years

Figure 6: Change in CO_2 atmospheric concentration (NOAA R. Lindsey, August 2020);

CO_2 during ice ages and warm periods for the past 800,000 years



9. NOAA's Annual Greehouse Gas Index (AGGI). 2020
10. NOAA, R. Lindsey, August 2020; Atmospheric carbon dioxide
11. OMM, 2020: The increase in global CO_2 concentration since 2000 is approximately 20 ppm per decade, which is up to 10 times faster than any sustained increase in CO_2 over the past 800,000 years (IPCC SP15).

3.2 The planet is warming

The increase in the concentration of GHG gases in the atmosphere is contributing to the increase of the greenhouse effect and **leading to an increase in temperature** (see Box).

Box 1. **Evidence of the influence of increased GHG concentration on temperature rise**

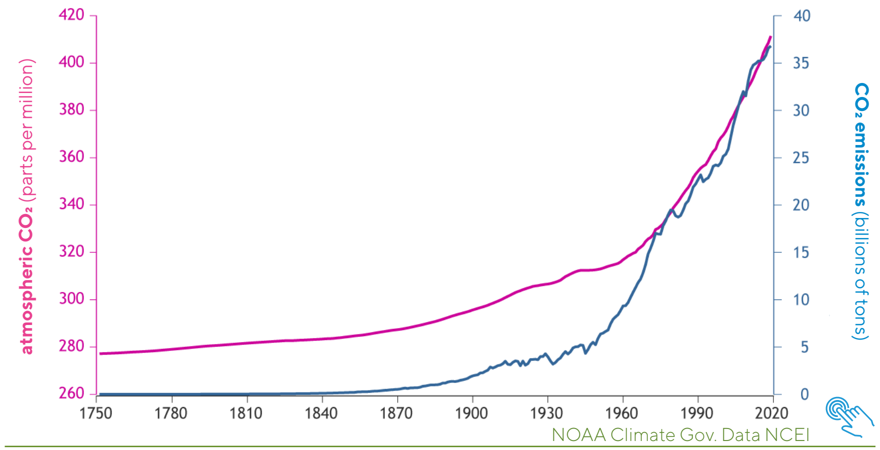
The fifth IPCC Assessment Report (AR5) concluded with a high level of confidence that human influence through GHG emissions has been the dominant cause of the warming observed since the mid-twentieth century. As indicated by the U.S. National Climate Assessment (USGCRP, NCA4, Vol. I, 2017), there are no alternative explanations supported by convincing evidence that can attribute to natural variability the magnitude and pattern of global warming seen over the last century during the industrial age. Changes in solar flux over the past six decades have been too small to explain the observed changes in climate and there are no apparent natural cycles in the observation record that can explain the recent changes in the climate. In addition, natural cycles within the Earth's climate system can only redistribute heat; they cannot be responsible for the observed increase in the global heat content of the climate system.

As shown in Figure (**b**), the rapid rate of temperature increase in such a short period of time points to the atmospheric addition of GHGs, mainly CO_2. Since the late 1950s, CO_2 has increased by almost 100 ppm, almost 5 times faster than in the first half of the observation record (~20 ppm). In the context of past natural glaciations, the increase observed over the past 60 years would have occurred over between 5,000 and 20,000 years. At the same time, the temperature has risen on average ~0.14°C per decade since 1950.

Box 1: Evidence of the influence of increased GHG concentration on temperature rise

a) Trend in CO_2 emissions and concentration 1750-2019 (NOAA, R. Lindsey, August, 2020)

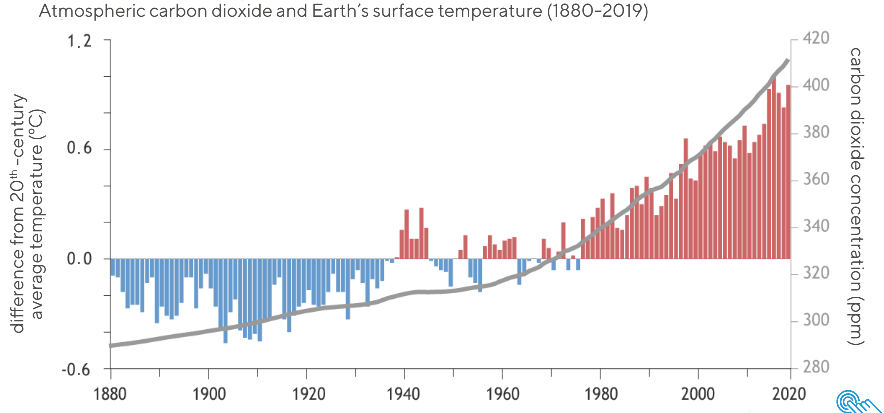
The increase in emissions is reflected in the CO_2 concentration



NOAA Climate Gov. Data NCEI

b) Trend in CO_2 concentration and surface temperature 1880-2019 (NOAA, R. Lindsey, February 2020)

The increase in CO_2 concentration (line) coincides with the increase in temperatures (bars)



NOAA Climate gov. Data ESRL/ETHZ/NCEI

- Global temperatures have been rising steadily since 1880, with 19 of the hottest 20 years since records began having occurred since 2001, with the exception of 1998[12].
- Thus, **2019 was the second warmest year on record**, with an average global surface temperature that exceeded that of the pre-industrial era (1850-1900) by ~1.1°C[13], with a greater increase over land than over the ocean.

This value has been surpassed only by the record of 2016, which was characterised by a very intense El Niño[14] episode, and it makes the five-year period 2015-2019 and the last decade the warmest ever recorded (WMO, 2020).

- **Since the 1980s, each successive decade has been warmer** than every previous one, with continuous warming in the range of 0.1°C to 0.3°C per decade (WMO, 2020).

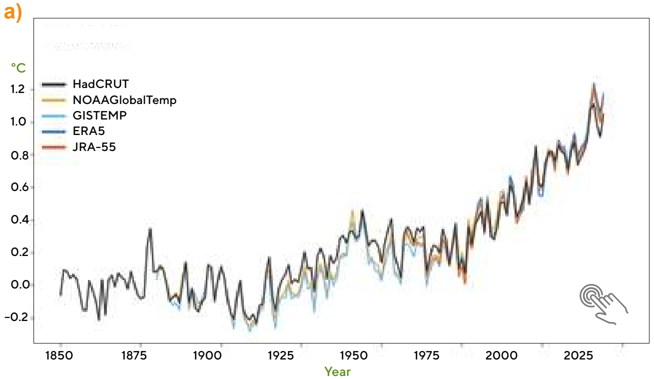
In most areas, both on land and in the ocean, conditions were warmer than the recent average (1981-2010).

Since the mid-1970s, temperatures on land have increased on average about twice as fast as those at sea. (Figure 7b).

Figura 7: Global average temperature change indicators (WMO, 2020)

Difference in global annual average temperature from pre-industrial conditions (1850-1900) based on 5 datasets

a)



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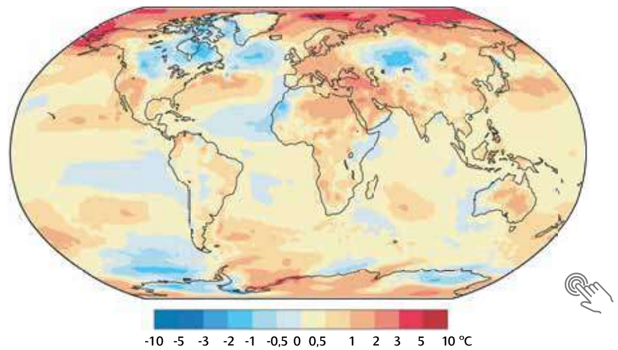
Surface air temperature anomaly in 2019 compared to the 1981-2010 average

b)



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12 https://climate.nasa.gov/vital-signs/global-temperature/

13. UAn increase in temperature of 1°C may not seem much if you think of daily or seasonal fluctuations, but it is a significant change when you think of an average permanent increase across the entire planet. A drop of just 5°C in the average global temperature is the difference between today's climate and an ice age (NASA).

14. El Niño-Southern Oscillation (ENSO) refers to a warming of water throughout the tropical Pacific Ocean basin associated with a fluctuation in the global tropical and subtropical surface pressure configuration. It most commonly occurs approximately every two to seven years. The cooling phase of ENSO is called La Niña (Glossary, AEMET)

3.3 The surface warming observed is related to other changes in the Earth's systems

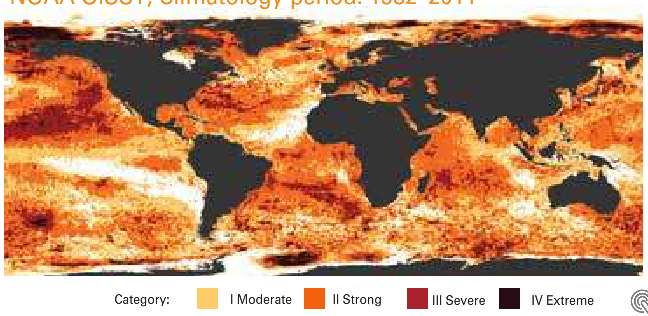
The oceans are warming

- **The ocean absorbs over 90% of the heat trapped in the Earth's system and, during 2019 its warming** (which is a measure of this heat accumulation) in the upper 700 m (in a series that began in the 1950s) and the upper 2000 m (in a series that began in 2005) continued at record or near record levels, with a current annual average so far exceeding the record levels set in 2018.
- **The frequency of marine heat waves has doubled since 1982 (IPPC, 2019b)**, and in 2019 at least 84% of ocean waters experienced at least one marine heat wave (MHW) (WMO, 2020).

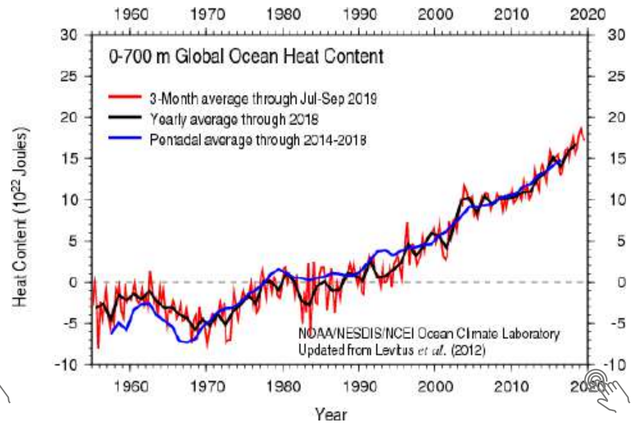
Figure 8: Ocean warming indicators (WMO, 2020)

a) World map showing the highest category of marine heat waves recorded in each pixel during the year (WMO, 2020)

MHW categories of 2019
NOAA OISST; Climatology period: 1982–2011



b) Ocean calorific content anomaly in the top 700 m relative to the average 1955-2006



90 %
of the **extra heat** is absorbed by the **oceans**

84 %
of **ocean waters** experienced at least **one marine heat wave in 2019**

23 %
of annual CO_2 emissions **are absorbed by the ocean, contributing to its acidification**

1-2 %
ocean oxygen inventory has been reduced

The oceans are acidifying and deoxygenating

Both the observations and the results from the models indicate a **reduction in oxygen** concentration in coastal and open sea waters, as well as in estuaries and semi-enclosed seas.

Since the middle of the last century, it is estimated **there has been a decrease of between 1% and 2% in ocean oxygen levels worldwide** (between 77,000-145,000 million tonnes).

While the relative importance of the various mechanisms underlying the decrease in oxygen levels is little understood, it is known that ocean warming decreases the solubility of oxygen and reduces the mixing between water layers and, as a consequence, the supply of oxygen and nutrients to the interior of the ocean (WMO, 2019a).

In addition, **during the decade 2009-2018, the ocean absorbed about 23% of annual carbon dioxide emissions**, attenuating atmospheric concentrations. However, **CO_2 reacts with seawater and lowers its pH, in a process called acidification**.

Observations from the last 20 to 30 years show a clear decrease in average pH, at a rate of 0.017–0.027 pH units per decade since the late 1980s, equivalent to a 26% increase in acidity.

This has a direct impact on the survival of coral reefs and various organisms with calcareous structures*, with cascading effects within the marine food web (WMO 2020).

Disappearing ice

Ice covers 10% of the Earth's surface and it is disappearing due to global warming. In addition, this melting influences climate change as glaciers have white surfaces that reflect the sun's rays and help keep our climate temperate.

When **the ice sheets melt**, darker surfaces, which absorb more heat, are exposed contributing to global warming.

- **Sea ice**: In the Arctic, monthly sea-ice extent values have decreased for every month of the year, and ice thickness has steadily declined ever since satellite data became available (1979 to present).

  In fact, the ice is getting younger (with a shorter formation-thaw period), making it thinner and more likely to melt in summer[15]. The extent of Antarctic sea ice had shown a small increase in the long term until 2016.

At the end of 2016, this was interrupted by a sudden drop in the surface area covered by ice to unprecedented lows. Since then, the area covered by Antarctic sea ice has remained relatively low (WMO, 2020).

- **Continental ice masses**: according to the IPCC (2019b) the loss of ice sheet mass during the period 2007-2016 tripled in Antarctica and doubled in Greenland from 1997-2006. The WMO indicates that in Greenland, 9 of the 10 years with the lowest ice sheet surface mass balance have been recorded in the past 13 years. And the seventh lowest value in the data set was recorded in 2019, with the reduction in the ice sheet set at 329 Gt, a value well above the average, with ~96% of the surface experiencing melting at least once.

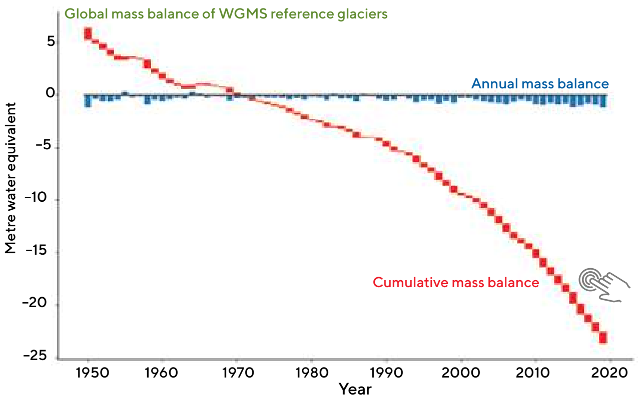
* NOAA PMEL Carbon program, Ocean Acidification

15 https://interactive.carbonbrief.org/when-will-the-arctic-see-its-first-ice-free-summer/

- **Glaciers**: The WMO indicates that, for the 32nd consecutive year, in 2018/2019, the mass balance of the selected reference glaciers was negative (Figure 9b). According to the IPCC (2019b) in high mountains, such as the Andes and the Himalayas, glaciers are retreating at unprecedented rates, 30% higher than a few decades ago.

Figure 9: Ice melting indicators

a) Annual (blue) and cumulative (red) mass balance for reference glaciers with more than 30 years of ongoing glaciological measurements (WMO, 2020)



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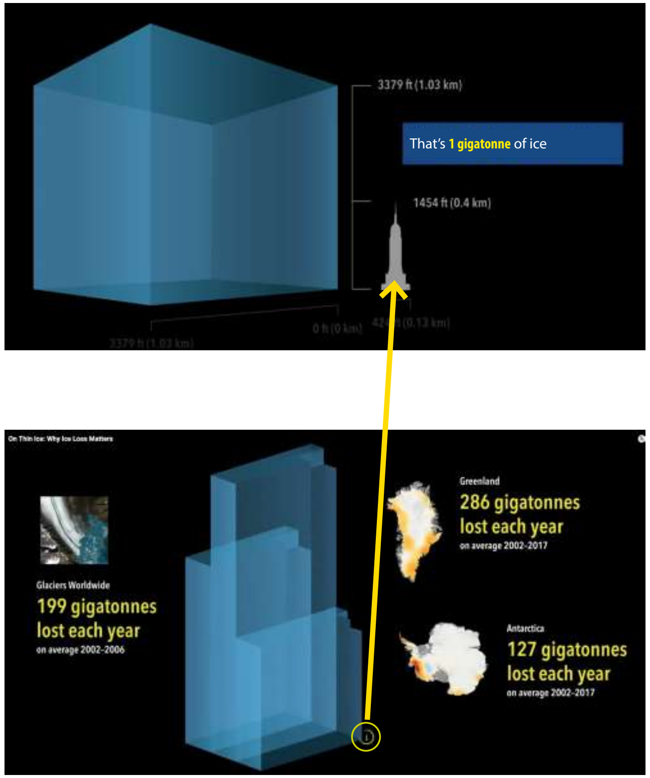
b) Graphic representation of the average annual reduction in the ice sheet in gigatonnes (Gt) between 2002-2017 (NASA, 2020)

Antarctica and Greenland lose an average 413 Gt of ice per year and glaciers 199 Gt.



See: @ NASA/JPL-Caltech, 2020, On Thin Ice: Why Ice Loss Matters

Submerged iceberg Greenland

Rising sea levels

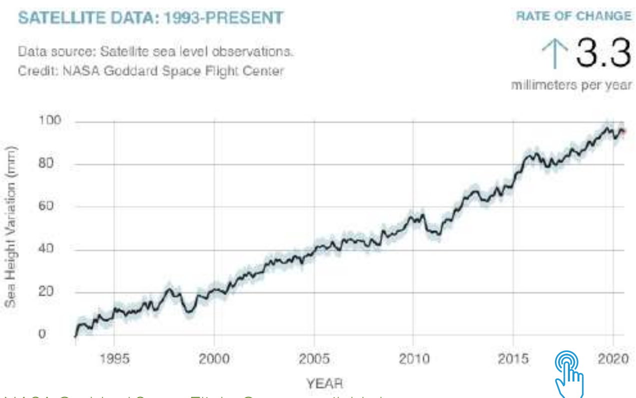
The accelerated loss of continental ice mass is the main cause of the increase in the rate of rise in the global average sea level (~55%), although ocean warming contributes more than 30% as a result of the thermal expansion of seawater. (OMM, 2020)

- During the twentieth century,the sea level rise on a global scale has been about 17.8 cm (NASA)[16].
- In **2019, the average sea level reached its highest level** since high-precision satellite records became available (January 1993) (WMO, 2020). The average rate of increase is estimated at 3.24[17] ± 0.3 mm/year in these 27 years, but the rate has increased during that time.
- Sea-level rise is not uniform across all regions, and depends primarily on geographic variations in ocean calorific content.

3 mm may not sound like a lot, but it equates to almost 42 trillion cubic meters of water

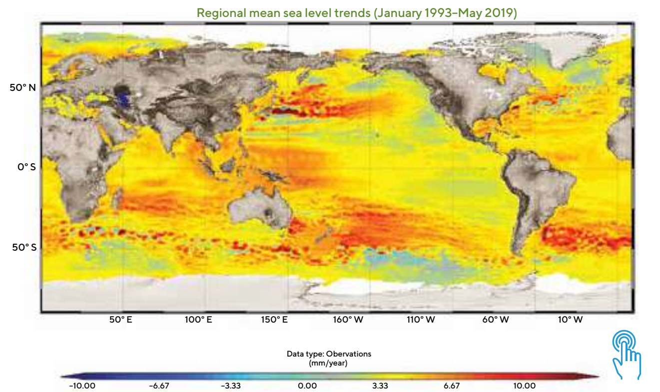
Figure 10: Sea level rise trend indicators

a) Global average sea level trend from January 1993 to October 2019. (NASA, 2020)



NASA Goddard Space Flight Center, available here: https://climate.nasa.gov/vital-signs/sea-level/

b) Regional variability in sea-level trends over the period 1993-2019, (WMO, 2020)



Extreme events

Extreme weather events are complex phenomena to study and even more difficult to predict because they are, by definition, rare/exceptional and obey different statistical laws from averages. However, there is general agreement that changes in the frequency or intensity of extreme weather and climate events are increasing in many regions as a result of global climate change.

The IPPC (SR15, 2018) indicates that changes in the intensity and frequency of many of these events, such as cyclones, heat waves or floods, have been observed since about 1950, based on several lines of evidence, including studies attributing specific events to climate change (see Box 2).

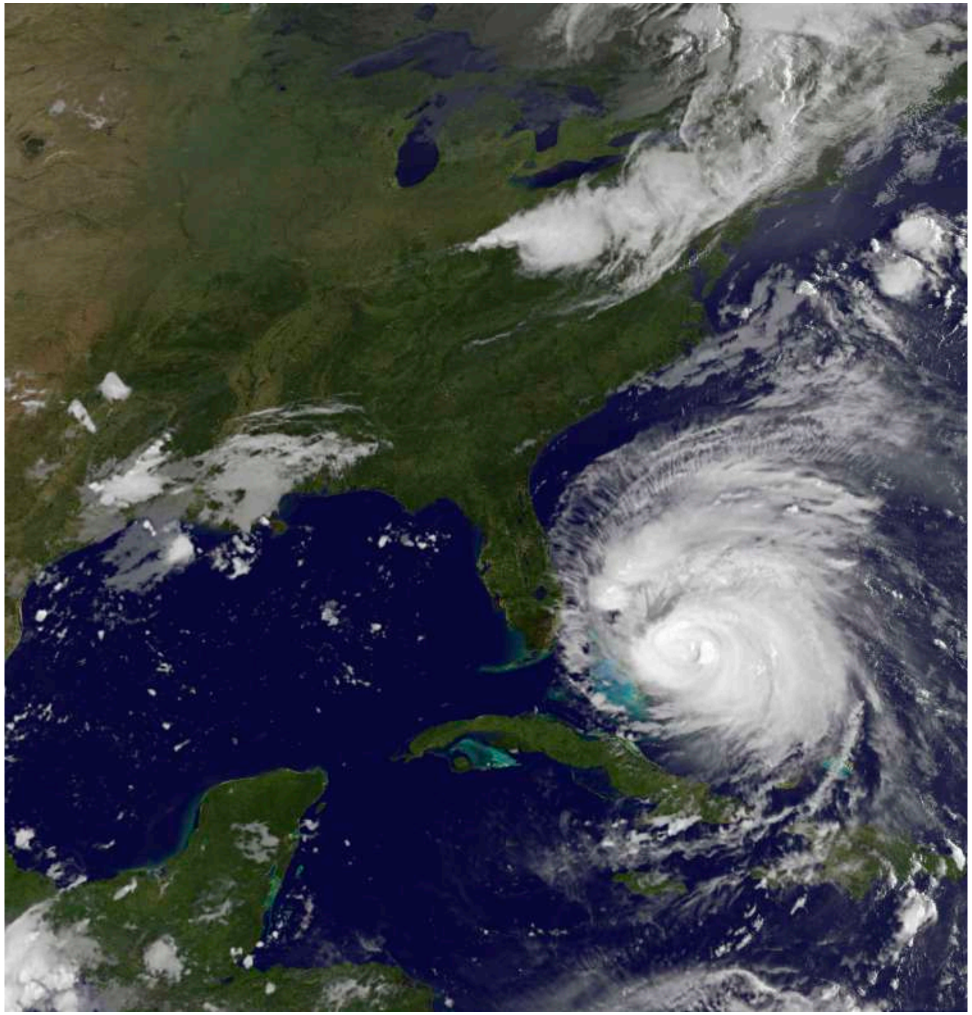
Similarly, the U.S. National Climate Assessment (NCA4 2017),indicates that there is high confidence that the frequency and intensity of extreme heat events and heavy rainfall are increasing in most continental regions of the world, these trends being consistent with expected physical responses to warmer weather.

With greater warming, the atmospheric water cycle intensifies, resulting in greater evaporation and torrential rains. As atmospheric layers heat up and

16. NASA/JPL-Caltech, 2020, Rising Tides: Understanding Sea Level Rise

17. While 3 mm may not seem much, it equates to nearly 42 trillion cubic metres of water (NASA /JPL-Caltech, 2020)

expand, storm clouds can grow in height and strength, leading to stronger rainfall.



Box 2. **Evidence of the influence of climate change on the frequency and severity of extreme events**

A recent study published by Carbon Brief has mapped each of the attribution studies published to date, giving a map* showing 355 extreme climate events that have taken place since the 2000s, and their worldwide trend. The analysis concludes that climate change has altered the probability of occurring or severity of extreme events in 78% of cases, with 69% becoming more likely and severe due to climate change and 9% less. The remaining 22% showed no influence or the results were inconclusive. Heat waves are the clearest attribution event, accounting for 47% of cases. Of the 125 studies that analysed heat wave events, 93% concluded that climate change has caused these events to become more severe and frequent.

Other events such as floods, extreme rain or droughts are more complex and therefore attribution is not so simple. In the case of extreme rain, of the 68 studies that analysed these types of events, 54% concluded that human activity has caused them to be more frequent or severe. However, while scientists have made progress in the field of attribution, there is a clear limitation in terms of the quality and availability of observed data and models, which means that the results obtained are not equally representative of all geographical locations around the world, with relatively few studies available for regions such as Africa.

* Carbon Brief's analysis (2020). Mapped: How climate change affects extreme weather around the world

Data from the WMO and NCA4, Vol. I, 2017 on the trends for major types of extreme events, indicate:

Heat waves: according to the WMO (2019b), heat waves were the deadliest weather hazard between 2015-2019, affecting all the continents and contributing to many new temperature records. Since 1998, the area on the Earth's surface seeing 30 days of extreme heat per year has almost doubled (NCA4, Vol. I, 2017). Virtually all the studies that have been conducted since 2015 on significant heat waves refer to the influence of climate change.

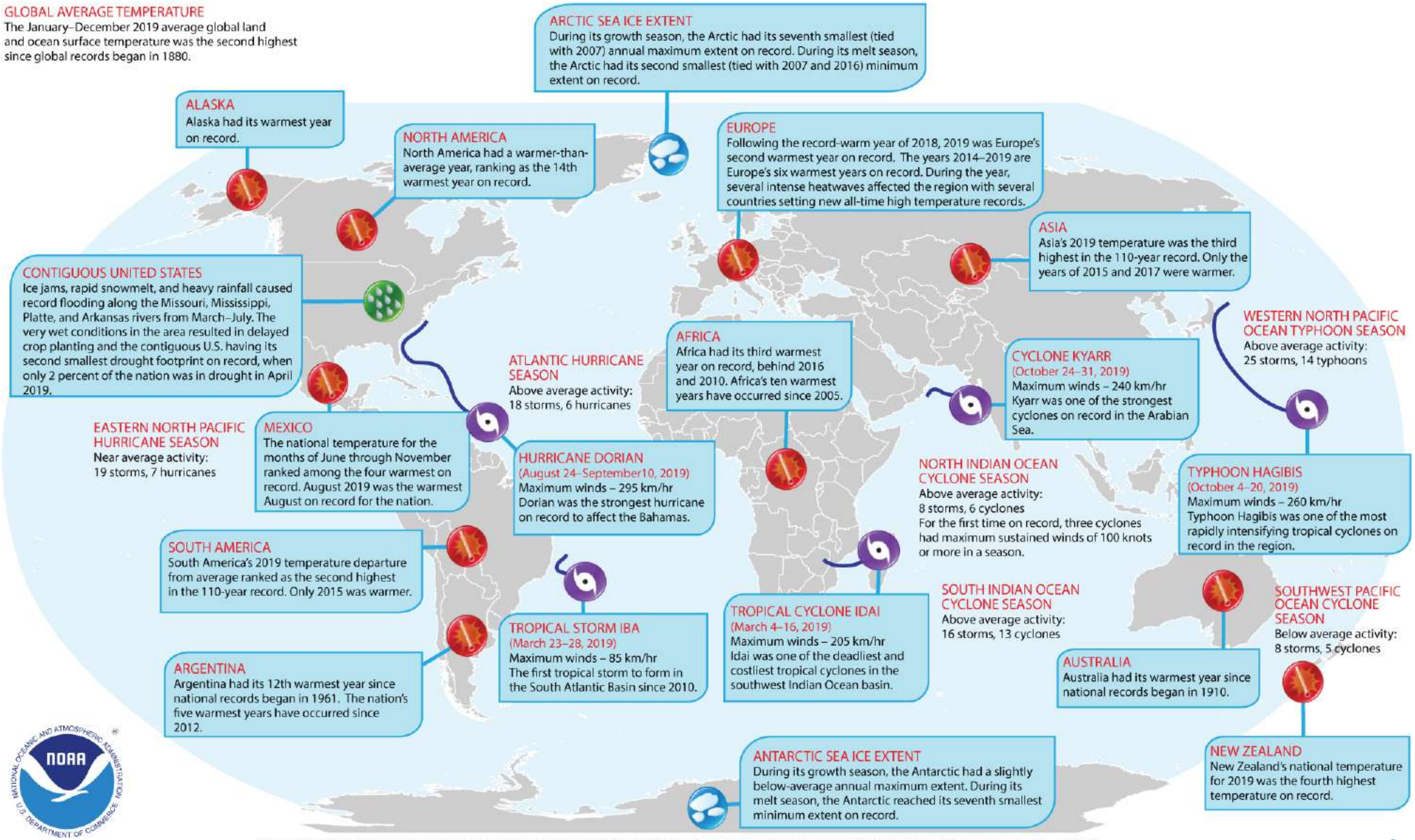
Heavy rainfall, storms and floods: According to the NCA4, extreme rainfall events are increasing in frequency globally in both wet and dry regions, although their impact on flood trends is complex, as other factors such as changes in soil cover are involved. Many of the studies on tropical cyclones indicate an increase in their probability and intensity, but significant uncertainties remain. One study* concludes that Category 3 or higher cyclones became 15% more likely globally between 1979-2017. According to the WMO, global tropical cyclone activity in 2019 was above the world average.

Droughts have had significant humanitarian and economic impacts in many parts of the world since 2015. Significant droughts occurred on all inhabited continents, but some of the greatest impacts occurred in Africa (WMO, 2019b).

Forest fires are strongly influenced by climate and phenomena such as drought. The three largest economic losses ever recorded are due to forest fires that took place in the last four years. In 2019, there were unprecedented wildfires in the Arctic and Australia, as well as widespread wildfires in the Amazon rainforest (WMO, 2019b).

* Kossin, J. P. et al. (2020) Global increase in major tropical cyclone exceedance probability over the past four decades, Proceedings of the National Academy of Sciences

Figure 11: Climatic anomalies and extreme events in 2019 (See more detail here: *NOAA, 2019*)



Please Note: Material provided in this map was compiled from NOAA's NCEI State of the Climate Reports and the WMO Provisional Status of the Climate in 2019.
For more information please visit: http://www.ncdc.noaa.gov/sotc

3.4 The consequences of these changes are obervable

Climate change, and particularly extreme events, greatly affect human well-being and all sectors of activity, both directly and indirectly, through their impacts on natural ecosystems and socio-economic systems. Some examples of this impact:

Table 5. Examples of climate change impacts

01

BIODIVERSITY

Climate change affects many aspects of biodiversity including species distribution, phenology, population dynamics, community structure and ecosystem function (IPBES, 2019). These impacts add to the effects of other human pressures on ecosystems, which are already affecting their vulnerability. This entails a **loss of quality of the goods and services provided by ecosystems** that act as a vital support for human activity (water, food, medicine, pathogen control, etc.).

47% of endangered land mammals, excluding bats, and 23% of endangered birds have already been adversely affected by climate change in at least part of their range (IPBES, 2019). Approximately half the live coral cover on coral reefs has been lost since the 1870s, with accelerating losses in recent decades due to climate change exacerbating other drivers (IPBES, 2019).

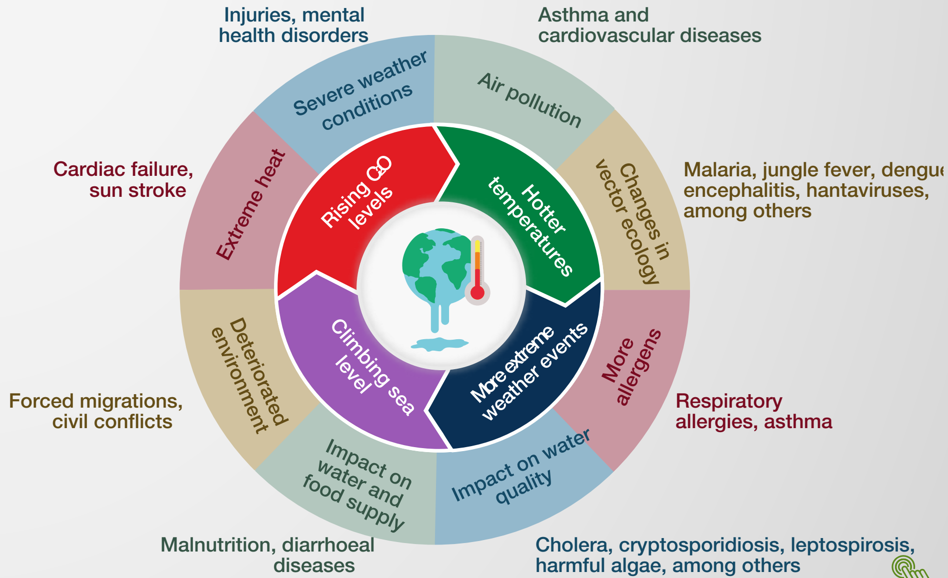
02

HEALTH

The World Health Organization (WHO), in its [2018 Special Report on health and climate change] specified that climate change was the biggest health challenge of the twenty-first century and threatens all aspects of our current society. The WHO reveals that the severity of climate change's effects on human health is becoming ever clearer for both the direct effects (e.g. exposure to higher temperatures, extreme events) and indirect ones through its impacts on natural ecosystems and their ability to provide essential goods and services (e.g. water, natural control of pathogens) and human systems (health, labour, conflict, malnutrition).

In 2018, the WHO estimated that climate change will cause an additional 250,000 deaths per year between 2030 and 2050. The WHO specifies that this is a conservative estimate, which only takes into account four of climate change's direct health effects, and therefore the health of hundreds of millions more people could be affected.

The effects of climate change



Source: CDC (Centre for Disease Control).

03

FOOD AND WATER SECURITY

Climate change has important **implications for the quality of the natural resources that are key to food supply**, as crops and livestock have physiological limits on their health, productivity and survival, including those related to temperature. To these are added the impacts of extreme events. Marine productivity is also affected by changes in the oceans (warming, acidification, etc.).

This can lead to one-off food crises or chronic impacts (e.g. malnutrition). It also affects the quality and availability of water, as it alters the amount and seasonality of rainfall, snow or ice melting or sea level, which in turn will have an impact on the health and productivity of ecosystems.

According to the WMO (2020), climate variability and extreme weather events are among the main **drivers of the recent increase in hunger in the world** (1 in 9 were hungry in 2018) and it is one of the main causes of severe crises.

04

POVERTY, CONFLICT, MIGRATION

These impacts will have a greater effect on those regions and populations with fewer economic resources due to their reduced capacity to adapt.

This can increase social instability, lead to or intensify migration flows from the most affected areas to the least affected areas, etc. In 2019, climate-related natural disasters caused 23.9 million human displacements[18].

In addition, **680 million people live in low-lying coastal areas**, making them very vulnerable to sea-level rise. Small Island Developing States are home to 65 million people (IPPC, 2019b).

18. IDMC's Global Report on Internal Displacement 2020 (y con el hipervínculo)

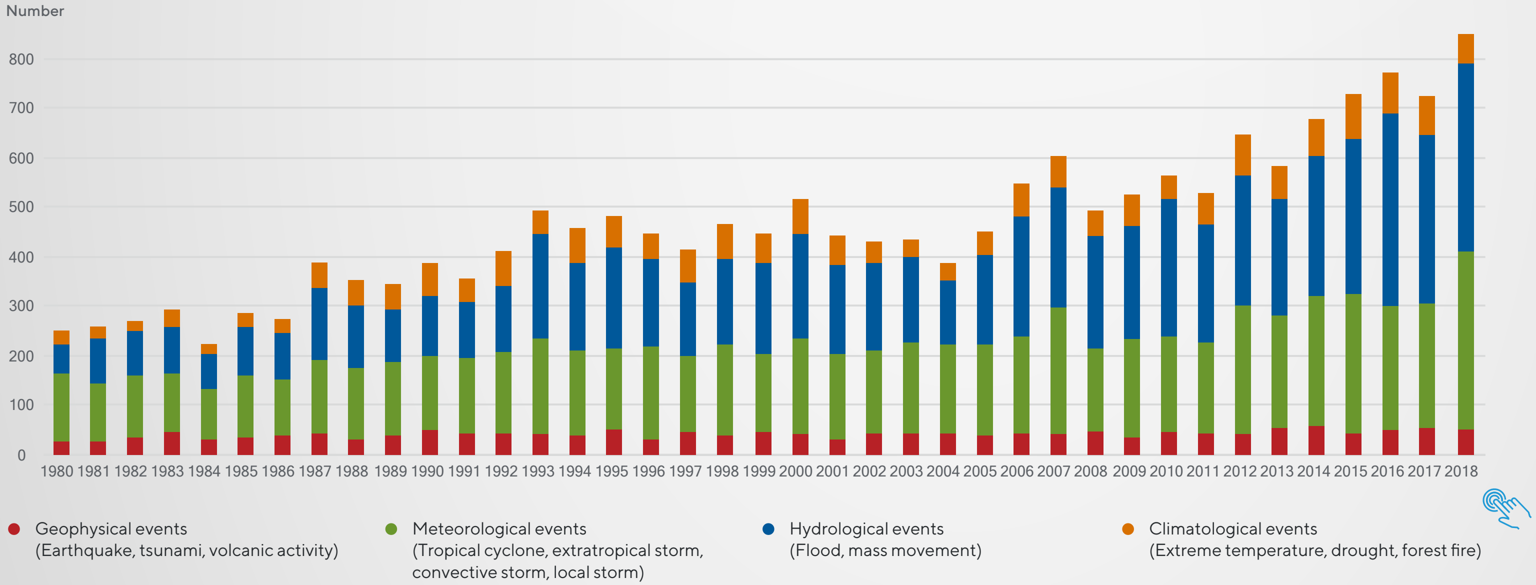
05

ECONOMIC SECTORS

Climate change is also considered one of the greatest threats to economic stability. Thus, every year, around the world, natural disasters result in human losses and destroy assets amounting to billions. Often, only a small proportion is insured, with a significant gap between industrialised countries and emerging and developing economies. Natural disasters caused overall losses of nearly $5 billion between 1980-2018, and less than a third were insured. The percentage of insured losses due to climate-related disasters has steadily increased to more than 90% by 2018. The number of climate-related events reached a record high in 2018, accounting for more than 80% of all recorded events[19].

Number of events

Catastrophic natural loss events worldwide 1980 – 2018



Accounted events have caused ≥ 1,000 fatalities and/or produced normalised losses ≥US$ 100m, 300m, 1bn, or 3bn (depending on the assigned World Bank income group of the affected country).

Source: Munich Re, NatCatSERVICE (2020)

19. Munich Re, NatCatSERVICE (2020) Relevant natural loss events worldwide 1980 – 2018

4 WHAT AWAITS US IN THE FUTURE

4.1 Emissions scenarios

The future climate will depend on the warming from past anthropogenic GHG emissions as well as future emissions and natural climate variability (IPPC, AR5, 2014). Multiple lines of evidence point to a solid and continuous near-linear relationship, in the different scenarios examined, between net cumulative CO_2 emissions (including the impact of CO_2 removal) and the projection of global temperature change up to the year 2100. It is therefore necessary to stabilise the atmospheric concentrations of greenhouse gases at a level that avoids dangerous interference with the climate system.

Based on scientists' recommendations, the international community has committed, with the signing of the Paris Agreement, to setting emission reduction targets to

keep the global average temperature rise well below 2°C compared to pre-industrial levels [20] , and to continue efforts to limit this increase to 1.5°C.

The IPCC (AR5) has estimated that **these limits imply an atmospheric CO_2 equivalent concentration of about 450 ppm (for 2°C) or 430 ppm (for 1.5°C) at the end of the century**. However, during 2020, unprecedented CO_2 levels have been recorded, with daily values reaching over 415 ppm [21].

The increase in global CO_2 concentration since 2000 is approximately 20 ppm per decade, which is up to 10 times faster than any sustained increase in CO_2 over the past 800,000 years (IPCC SP15). The result is that the

20. The IPCC (SR15, 2018) uses the reference period 1850-1900 to represent the pre-industrial temperature.
21. https://climate.nasa.gov/vital-signs/carbon-dioxide/

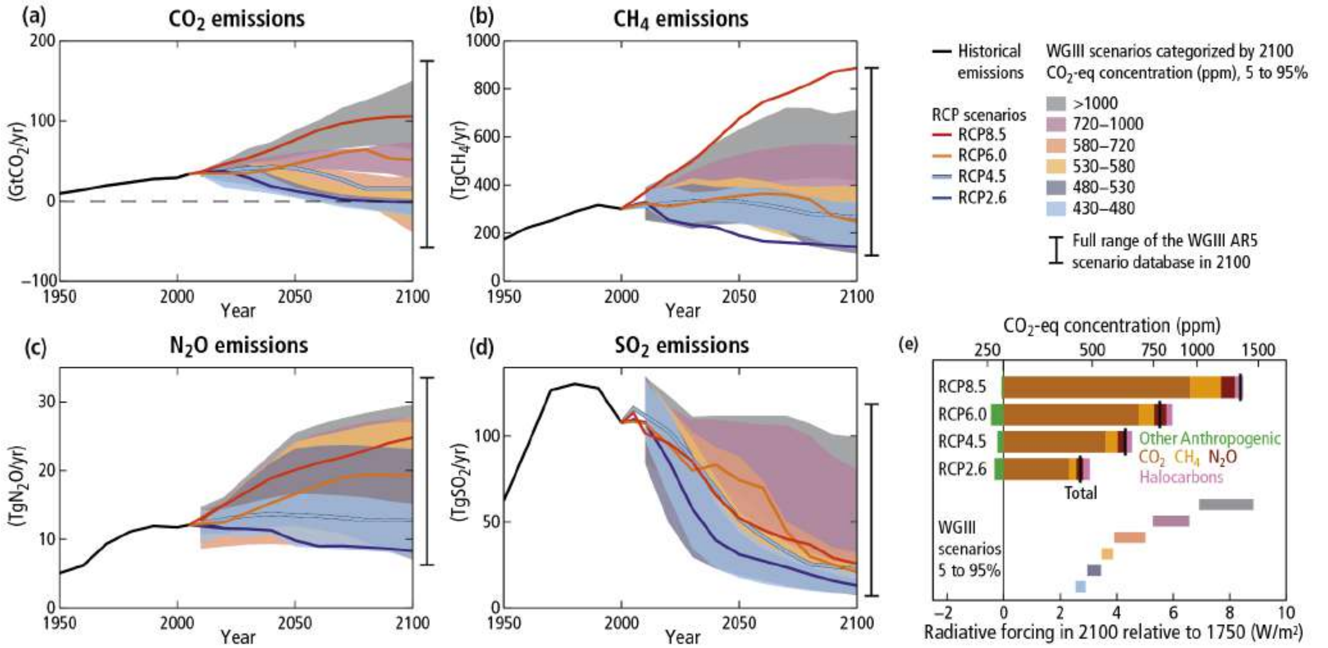
global temperature is increasing by around 0.2°C per decade, and if this rate continues, the IPCC (SR15 2018) predicts that human-induced global warming of 1.5°C would be achieved around 2040. In addition, it is important to bear in mind that this warming is not homogeneous across the planet, and in many regions the limit of 1.5°C has already been exceeded.

Therefore, the projections regarding greenhouse gas emissions have a wide margin of variation, depending on socio-economic development and climate policy.

The last IPCC Assessment Report (AR5, 2014) defined a group of scenarios called "Representative Concentration Pathways" [22] (RCP) which are used to make projections.

These include a strict mitigation scenario (RCP 2.6) aligned with keeping the temperature increase below 2°C, two intermediate emissions stabilisation scenarios (RCP 4.5 and RCP 6.0), and a very high emission scenario (RCP 8.5).

Figure 12: Representative concentration pathways (RCP)



© IPCC, AR5, 2014

IPCC, AR5

In timescale terms, the physical effects of climate change are similar for all the scenarios in the short-term, due to the effect of accumulated emissions and inertia in the climate system, with the 1.5°C limit expected to be reached around 2040, if current growth rates are maintained (IPCC SR15, 2018). Therefore, there will be some inevitable change in the future, which will require adaptation measures (see Figure 13b). The greatest variation in physical results arises in the second half of the century, depending on the actions taken in the coming decades. In the absence of large-scale mitigation actions, warming of 3-4°C by the end of the century is most likely, although there is also a risk of exceeding 5°C which would have serious consequences. However, with a rapid reduction in global emissions it is still possible to limit the temperature increase to below 2°C by 2100 [23].

22. They describe four different trajectories over the course of the twenty-first century for greenhouse gas emissions and atmospheric concentrations, emissions of air pollutants (aerosols) and land use. These are characterised by their total radiative forcing for the year 2100, ranging from 2.6 to 8.5 W/m2, depending on the scenario. The projections for the different climate variables are obtained from general circulation models (GCM). Over the past 20 years, numerous models have been developed. The fifth IPCC report uses the results from the CMIP5 project (Coupled Model Intercomparison Project) as a general benchmark.

23. According to the IPCC (SR15, 2018) warming caused by anthropogenic emissions from the pre-industrial period to the present will last from centuries to millennia and will continue to cause new long-term changes in the climate system, such as sea level rise, accompanied by associated impacts; however, these emissions alone are unlikely to cause warming above 0.5°C over the next two or three decades or on a one-century time scale.

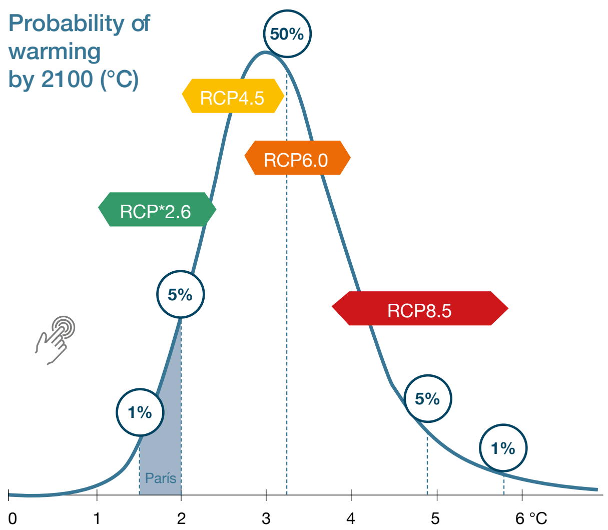
The IPCC (SR15, 2018) states that in order to limit warming, it is necessary to.

- ✓ *Objective - 1.5°C - reduce emissions by 45% by 2030 compared to 2010 and net zero emissions by 2050.*
- ✓ *Objective -2°C - reduce emissions by 20% by 2030 compared to 2010 and net zero emissions by 2075.*

According to a recent report by UNEP (2019), this translates into the need to reduce emissions by 7.6% annually from 2020 to 2030 for the target of 1.5°C and 2.7% annually for the target of 2°C.

Figure 13: Emissions scenarios, based on IPPC data

a) Probability of warming (CRO Forum, 2019)



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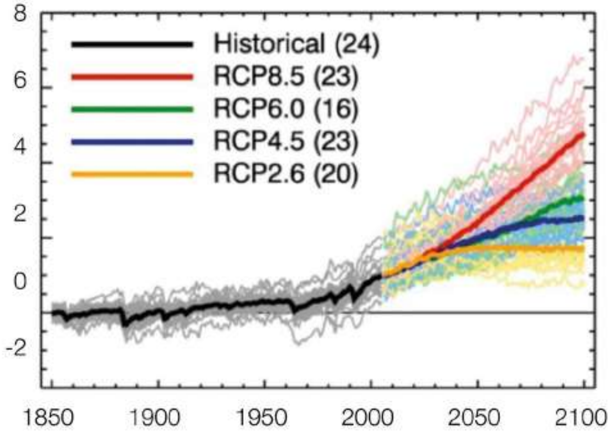
The heat is on, insurability and resilience in a changing climate

b) Temperature increase range for each RCP



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Scenario	Range of probable increase	Expected average increase
RCP 2.6	0.3°C - 1.7° C	1° C
RCP 4.5	**1.1° C - 2.6° C**	**2° C**
RCP 6.0	1.4° C - 3.1° C	2.5° C
RCP 8.5	**2.6° C - 4.8° C**	**4° C**

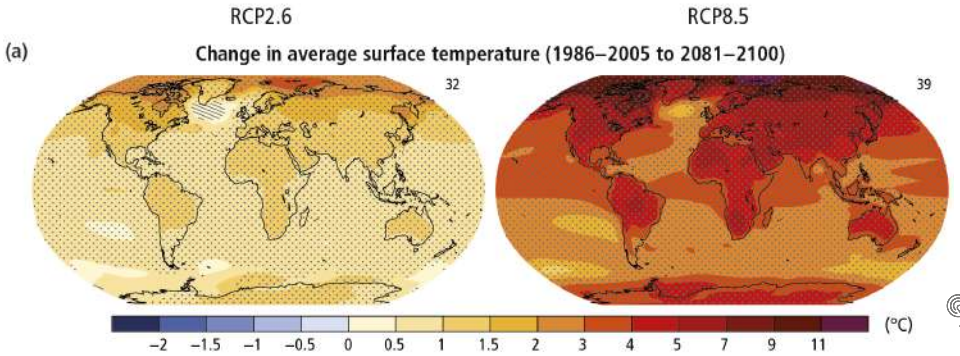
4.2 Climate projections

Climate projections are technical simulations performed by the IPCC on climate trends during the twenty-first century according to the RCP scenarios for GHG emissions. Based on the conclusions of the main IPCC reports, the expected changes for the main climate variables previously analysed up to 2100 for various future climate scenarios are detailed below, contrasting the differences between a high emission scenario (RCP 8.5) and a moderate scenario (RCP 2.6) and those compatible with limiting warming to 1.5°C or 2°C.

Table 6. Projections of changes for major climate variables (IPCC reports)

TEMPERATURE

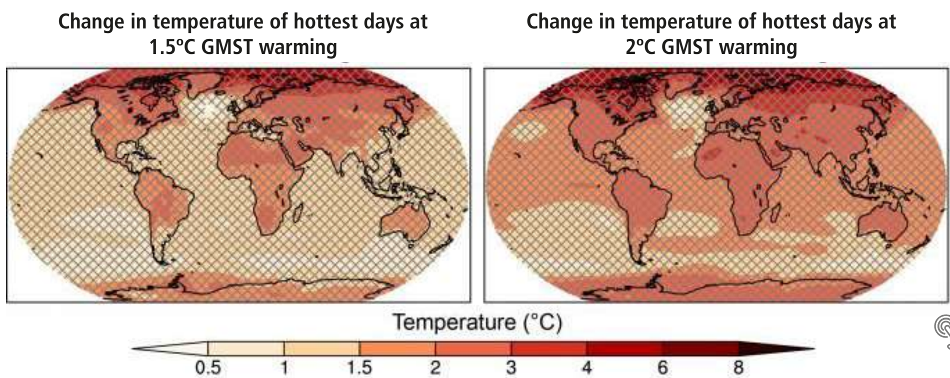
The change in the global average surface temperature for the period 2016-2035 compared to the period 1986-2005 is similar for the four RCP scenarios and is likely to be in the range of 0.3°C to 0.7°C (medium confidence level), provided that no major changes in natural variability occur. From 2050 onwards, the magnitude of the projected climate change varies considerably depending on the chosen emission scenario (IPPC, AR5).



EXTREME TEMPERATURES

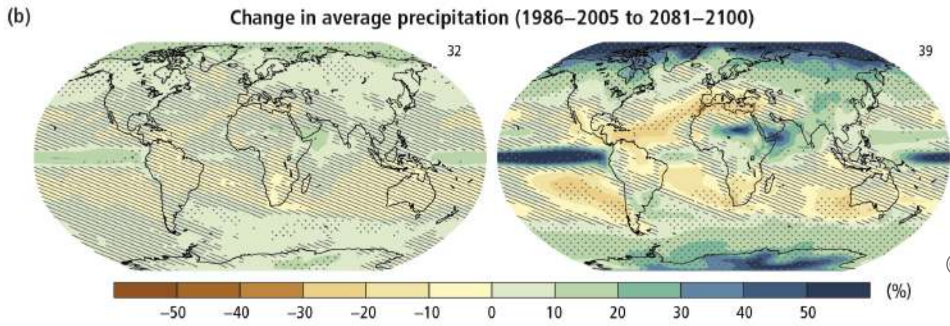
It is almost certain that more frequent extreme hot temperatures and less frequent cold temperatures will occur in most continental areas, on daily and seasonal timescales. It is highly likely that there will be more frequent and longer lasting heatwaves. Extreme cold temperatures will continue to occur occasionally in winter (IPPC, AR5).

Extreme temperatures on land will increase more than the global average surface temperature and will be more pronounced with a warming of 2°C than 1.5°C. The number of warm days will increase in most terrestrial regions, with the greatest increases in the tropics (IPPC, SR15).



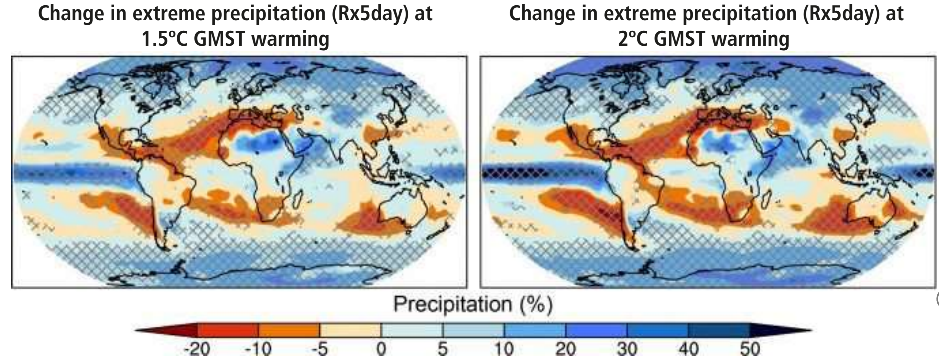
RAINFALL

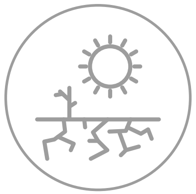
The changes in rainfall in a warming world will not be uniform. By the end of this century, the higher latitudes and the equatorial Pacific Ocean are likely to experience an increase in average annual rainfall under the RCP8.5 scenario. Under scenario RCP8.5, mean rainfall is likely to decrease in many dry mid-latitude and subtropical regions, while mean rainfall is likely to increase in many wet mid-latitude regions. (IPPC, AR5).



EXTREME RAINFALL

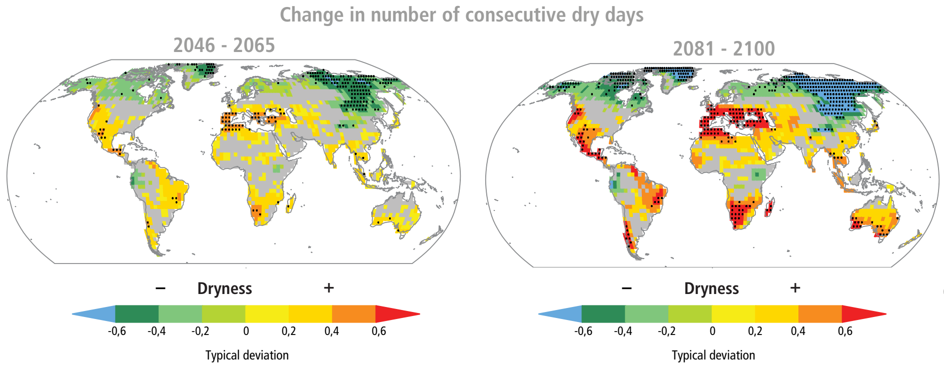
Extreme rainfall events are most likely to be more intense and frequent in most land masses at mid-latitude and in humid tropical regions (IPPC, AR5). It is estimated that the risks of heavy rainfall events will be greater with global warming of 2°C than with global warming of 1.5°C in several high-latitude or high-altitude regions in the northern hemisphere, East Asia and East North America (IPPC, SR15).





DROUGHT

There is a medium level of confidence that droughts will intensify in the twenty-first century in some areas and seasons due to decreased rainfall and/or increased evapotranspiration. This is the case in southern Europe and the Mediterranean, central Europe, the central zone in North America, Central America and Mexico, north-eastern Brazil and southern Africa. (IPPC, SREX, 2012).



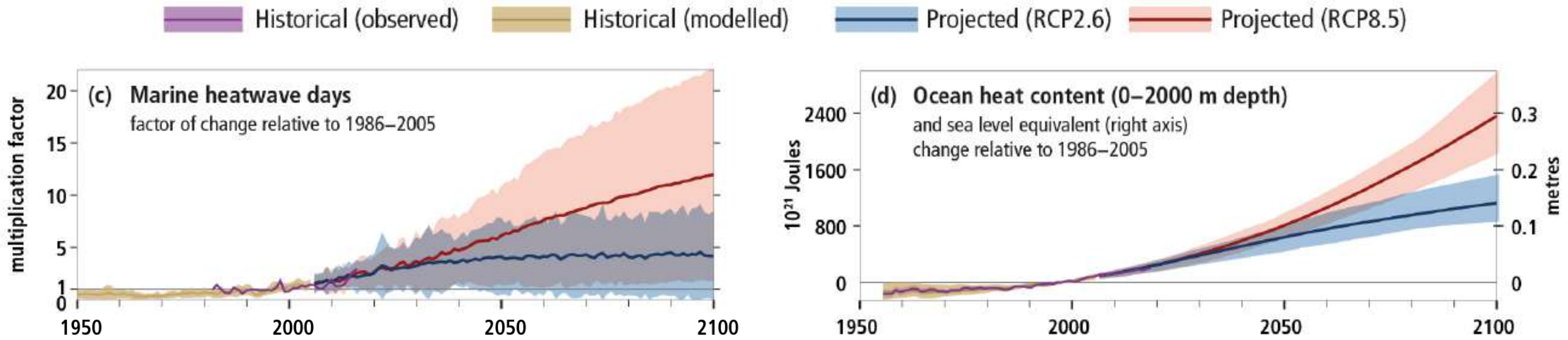
WEATHER PATTERNS

Extreme El Niño and La Niña events are expected to increase in frequency in the twenty-first century, with drier or wetter responses in various regions around the world. Extreme El Niño events are expected to occur approximately twice as often under RCP2.6 and RCP8.5 in the twenty-first century versus the twentieth century (average confidence). Extreme events related to the Indian Ocean Dipole also increase in frequency (low confidence). (IPPC, SROCC, 2019)

OCEAN WARMING

By 2100, the oceans will absorb 2 to 4 times more heat under a low-emission scenario (RCP2.6) and 5 to 7 times more heat in the high-emission scenario (RCP8.5) compared to the changes observed since 1970. Under the RCP8.5 scenario, the ocean is very likely to absorb twice as much heat as in RCP2.6. Even under RCP2.6 the ocean will continue to warm for several centuries.

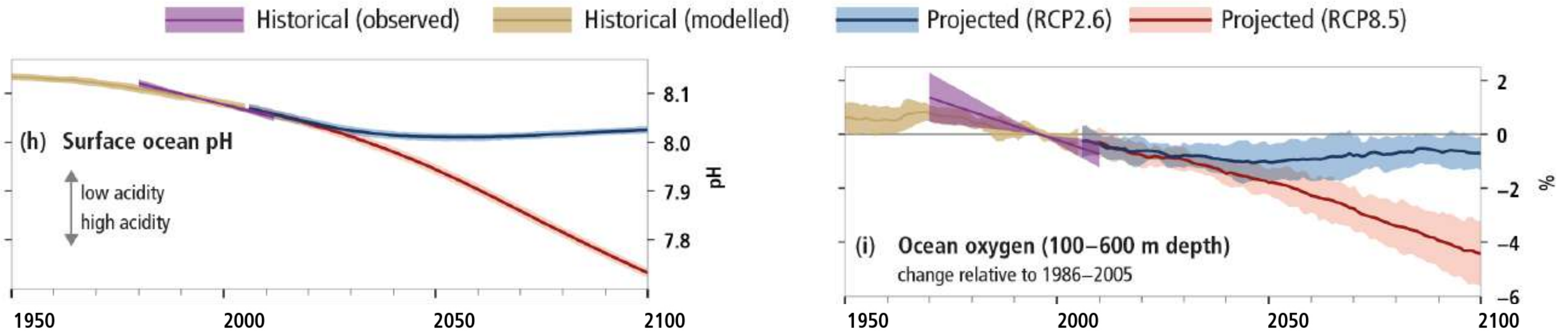
In addition, the projections point to a further increase in the frequency, duration, extent and intensity of marine heat waves. With warming of 2°C, their frequency, which has already doubled since 1982, will be 20 times higher compared to pre-industrial levels, and may be up to 50 times higher if emissions continue to rise sharply. (IPPC, SROCC)



ACIDIFICATION AND DEOXYGENATION

By 2081-2100 according to RCP8.5, the ocean's oxygen content is expected to decline globally by highly probable ranges of 3-4% compared to 2006-2015. (IPPC, SROCC)

Continued carbon addition to the oceans by 2100 will exacerbate the increased acidity of their waters. The increase in acidity of the surface ocean's pH will be in the range of 15-17% for RCP2.6 and reaches 100%-109% for RCP8.5. (IPPC, AR5)



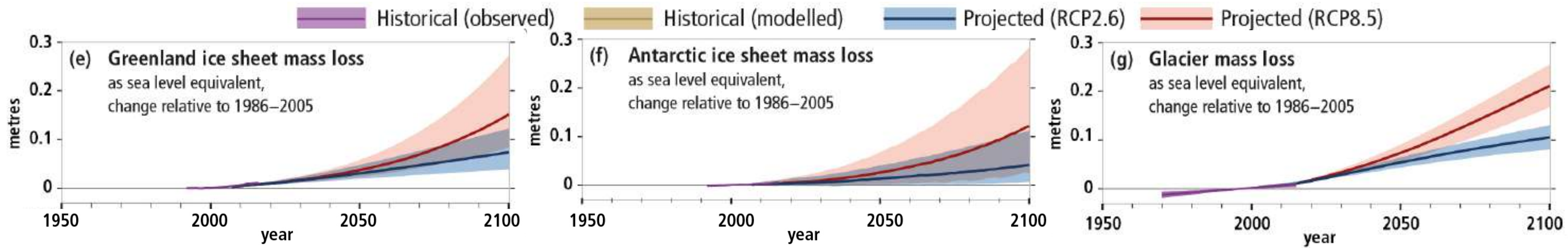
ICE

Current trends in glacier mass loss, permafrost melting and decline in Arctic snow and ice cover are expected to continue throughout the twenty-first century. (IPPC, SROCC)

It is, therefore, anticipated that 80% of the current ice layer in glaciers in places such as Europe could disappear under high-emissions scenarios.

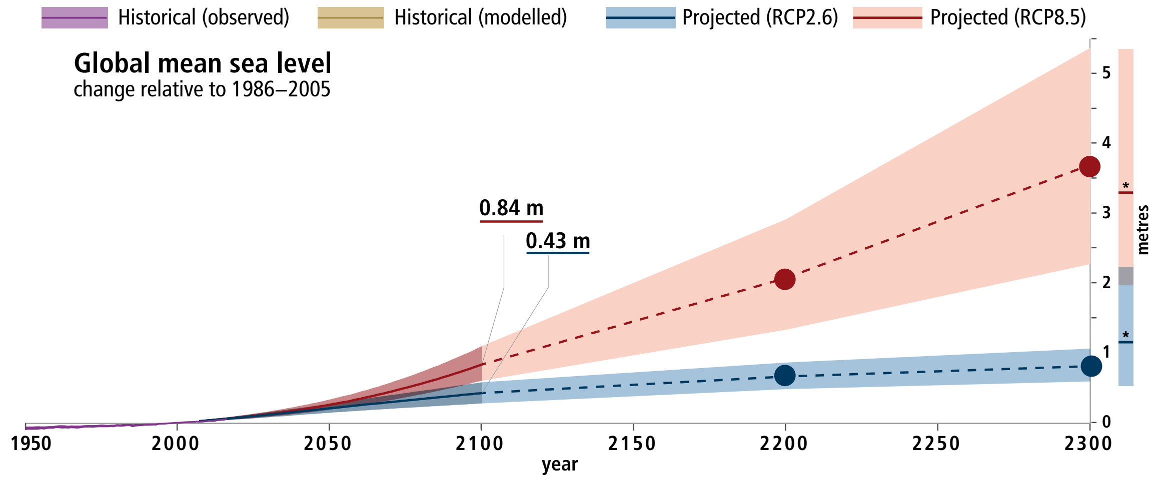
In a 1.5-degree scenario, we could see an ice-free September in the Arctic every 100 years and every 3-10 years in a 2-degree scenario.

Even if global warming is limited to well below 2°C, approximately 25% of the near-surface permafrost (3-4 metres deep) will have been thawed by 2100.



RISE IN SEA LEVEL

Sea level will continue to rise for centuries. Up to 2100, it could rise between 30-60 cm even if global warming remains well below 2°C. However, in a high-emissions scenario, the rise could be in the order of 60-110 cm. In the longer term, the estimates are even more worrying, with an increase of up to 5.4 metres by the year 2300 in a high-emissions scenario. (IPPC, SROCC)



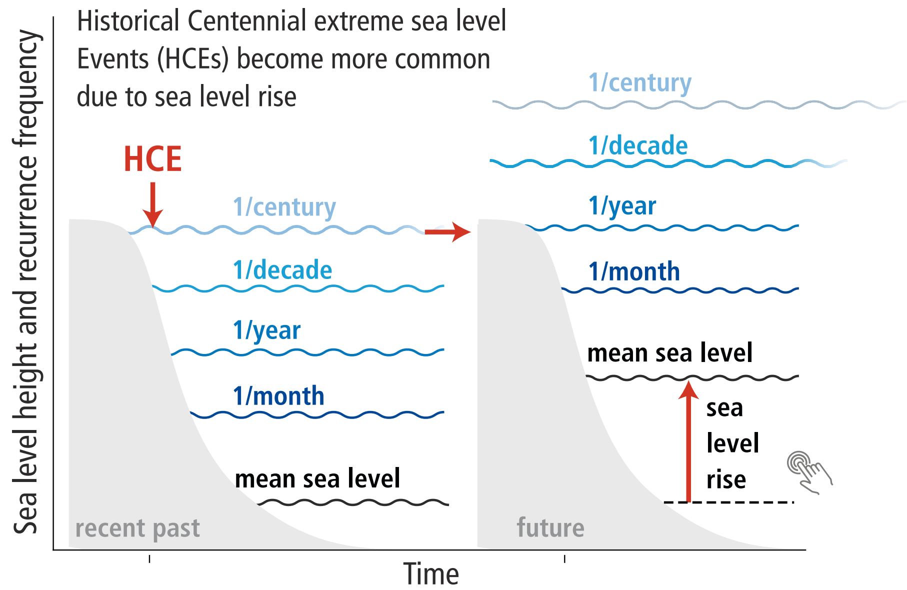
EXTREME SEA EVENTS

Rising sea levels will increase the frequency of the extreme sea events that occur, for example, during high tides and intense storms. Increased winds and precipitation associated with tropical cyclones will exacerbate extreme sea level episodes and coastal hazards.

With each additional degree of warming, events that used to occur once every 100 years will occur annually by 2050 in many regions, aggravating the risks to which many small islands and low-lying coastal cities are exposed. (IPPC, SROCC)

Note: The reliability of the **projected changes** varies with the type of variable and with the region, as well as with the season under consideration. Based on the information provided by the IPCC[26], it could be concluded that: 1) there is a **high degree of confidence** in projections related to extreme temperatures and sea level; 2) **confidence is lower** in the case of extreme rainfall and droughts; 3) overall, there is **little confidence** in the predictions relating to extreme events such as winds, river floods, dust storms, natural weather modes (El Niño, Indian Ocean Dipole, etc.).

Schematic effect of regional sea level rise on projected extreme sea level events (not to scale)



© Intergovernmental Panel on Climate Change (IPCC), SROCC, 2019

The projections cover a broad timescale, up to the end of the century. In the short term, the WMO indicates[27] that a new world average temperature record is likely to be set in the next five years (2020-2024), particularly in high-latitude regions and terrestrial areas, and that ocean warming will be slower, especially in the North Atlantic and Southern Ocean.

With regard to the potential impact of the Covid-19 pandemic, the WMO indicates that since CO_2 remains in the atmosphere and in the oceans for centuries, the world is set to a certain level of continuous change regardless of any transient reduction in emissions.

On the other hand, it makes it difficult to tackle meteorological, climatic and hydrological risks, the severity of which only increase due to climate change.

In addition, 2020 is set to be a record year[28], having already experienced the second warmest start to the year after 2016, which was affected by El Niño.

26. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf
27. https://public.wmo.int/es/media/comunicados-de-prensa/el-d%C3%A-Da-de-la-tierra-hace-hincapi%C3%A9-en-la-acci%C3%B3n-clim%C3%A1tica
28. https://www.carbonbrief.org/state-of-the-climate-first-quarter-of-2020-is-second-warmest-on-record

4.3 Projection regarding potential impacts and associated risks

The scenarios are estimates of possible future climate features and serve as a reference for developing specific impact and vulnerability studies for various ecological, economic and social sectors and systems. The following figure from the paper "*The Heat is On - Insurability and Resilience in a Changing Climate*' (CRO Forum) highlights some of the differences between the expected impacts of an increase in the average temperature of the planet of 1.5°C compared to 2°C, as well as the impacts of an increase of 3°C or 5°C based on IPCC information. These risks depend on the magnitude and pace of warming, geographical location and levels of development and vulnerability, as well as adaptation and mitigation options.

Figure 14: Comparison between some expected impacts in 2100 for various scenarios (CRO Forum/IPCC, 2019)

Warming by 2010		<2 °C		3 °C	5 °C
Physical impacts		1.5 °C	2 °C		
Sea-Level Rise (cm)		0.3-0.6 m	0.4-0.8 m	0.4-0.9 m	0.5-1.7 m
Coastal assets to defend ($tn)		$10.2tn	$11.7tn	$14.6tn	$27.5tn
Chance of ice-free Arctic summer		1 in 30	1 in 6	4 in 6 (63%)	6 in 6 (100%)
Tropical cyclones:	Fewer (#cat 1-5)	-1%	-6%	-16%	Unknown
	Stronger (# cat 4-5)	+24%	+16%	+28%	+55%
	Wetter (total rain)	+6%	+12%	+18%	+35%
Frequency of extreme rainfall		+17%	+36%	+70%	+150%
Increase in wildfire extent		x1.4	x1.6	x2.0	x2.6
People facing extreme heatwaves		x22	x27	x80	x300
Land area hospitable to malaria		+12%	+18%	+29%	+46%

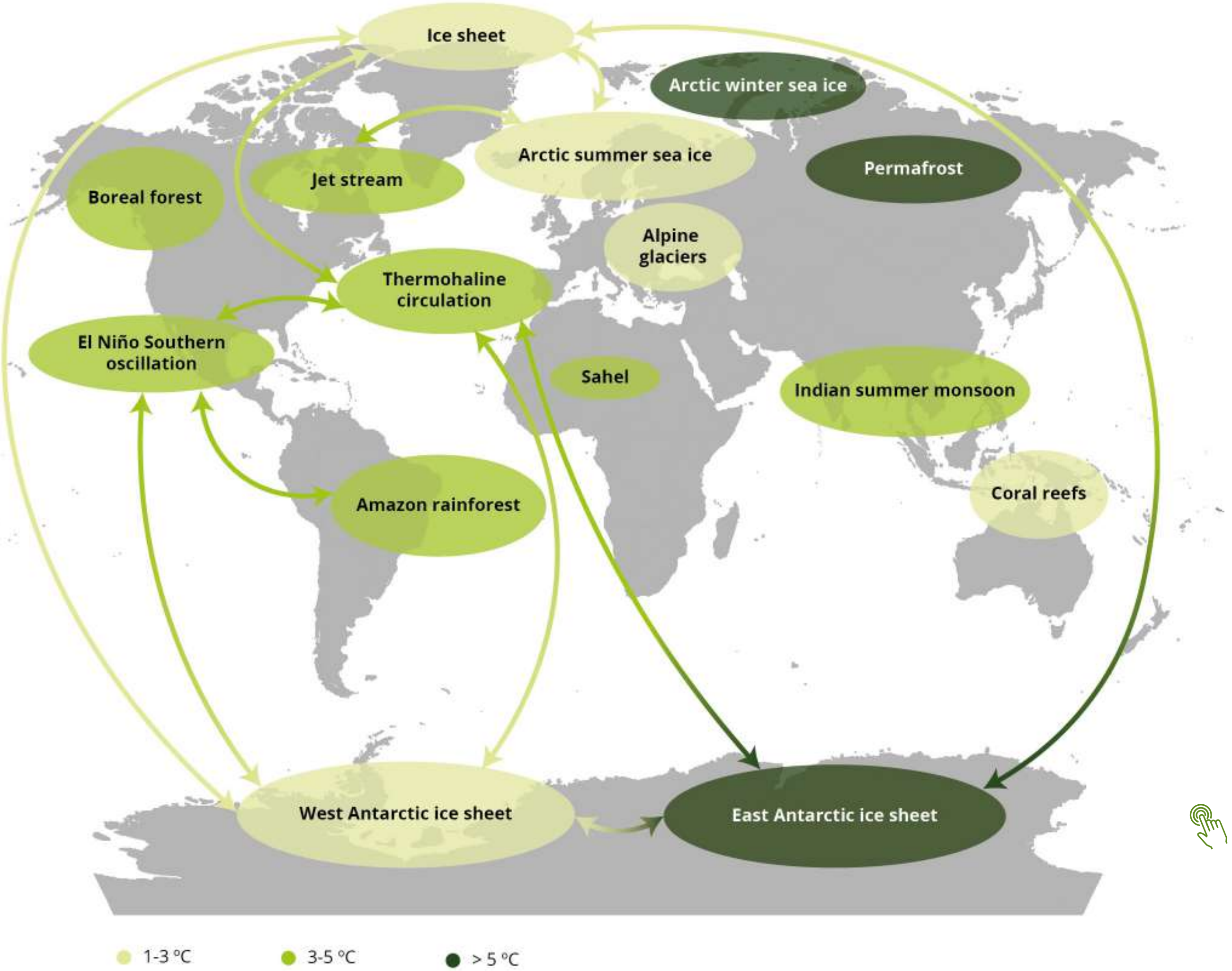
The projections highlight the importance of achieving global climate neutrality in the short term (2050) in order to limit the increase in global temperature by 2100 to below 1.5°C, thus minimising the magnitude of the problem in the medium and long term. It is true that stabilising the global average surface temperature does not imply the stabilisation of all aspects of the climate system, and many aspects (e.g. sea level rise) will continue for centuries. But every tenth of a degree temperature rise is important as the impacts increase rapidly, even exponentially.

The IPPC (SR15) warns of the risks posed by an increase of 1.5°C at the end of the century, even compared to a 2°C scenario. The comparison between the two shows substantial changes in average and maximum global temperatures, with some regions experiencing a warming between 2 and 3 times higher compared to the average in a 2°C scenario. Thus, limiting warming to 1.5°C would reduce the number of people exposed to extreme heat waves by 420 million and limit to approximately half the world's population those exposed to water scarcity compared to a 2°C scenario. It also highlights the importance of the emissions trajectory, with future risks depending on the pace, peak and duration of warming. Overall, these are higher if global warming exceeds 1.5°C before returning to that level by 2100, than if global warming gradually stabilises at 1.5°C.

At higher temperature rises of 3-4°C, several tipping points are almost certain to be crossed, with abrupt and irreversible changes in ecosystems or climate patterns, which will limit our ability to adapt

At higher temperature rises of 3-4°C, several tipping points are almost certain to be crossed, with abrupt and irreversible changes in ecosystems or climate patterns, which will limit our ability to adapt. The transgression of certain "thresholds" by components of the Earth's system implies a change to a completely new state that can be difficult to reverse and can trigger positive feedback loops or cascading impacts with other elements that may even accelerate warming. In this regard, one study[29] warns that irreversible changes may begin to reshape the world's ecosystems in the coming years, as climate limits are exceeded virtually simultaneously in most species in each ecosystem.

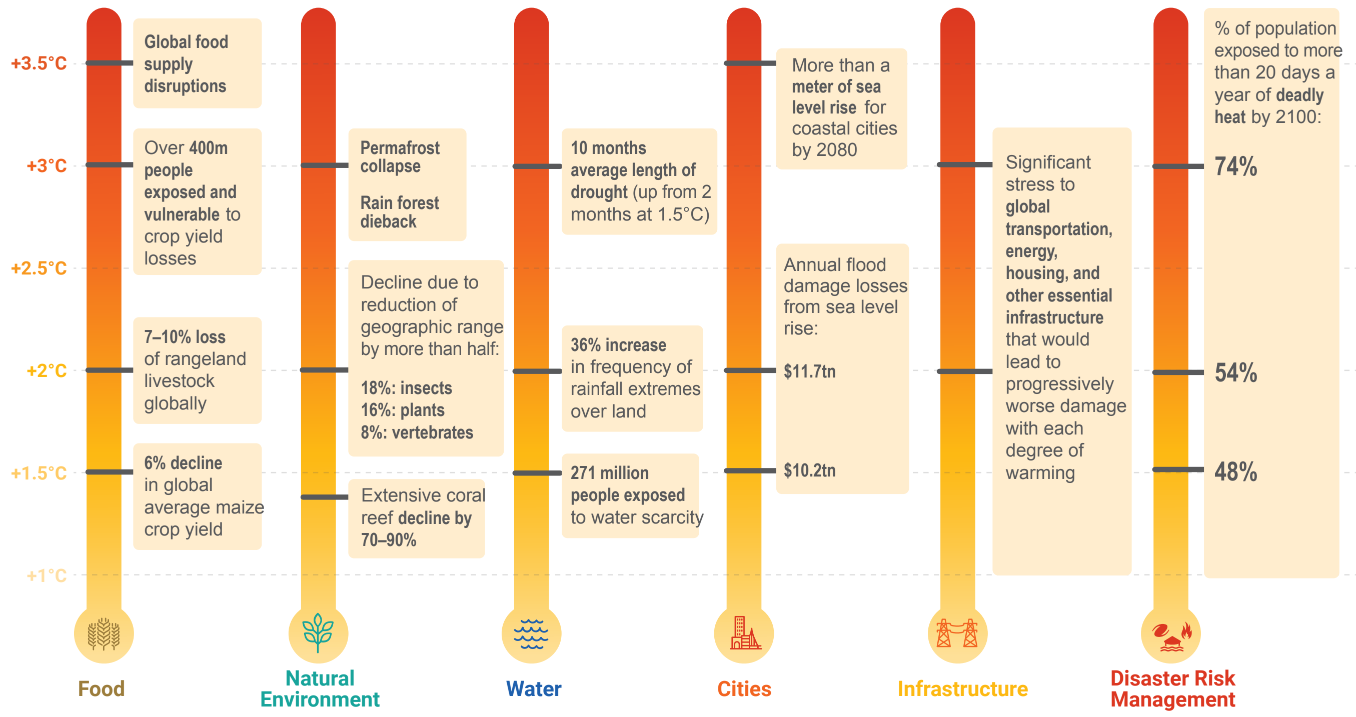
Figure 15: Possible tipping points and cascading effects according to estimated thresholds for global average surface temperature (AEMA, 2019)



29. Trisos, C.H., Merow, C. & Pigot, A.L. The projected timing of abrupt ecological disruption from climate change. Nature 580, 496–501 (2020).

Climate change will, therefore, aggravate existing risks and create new risks for natural and human systems. Figure 16 describes the magnitude and severity of the consequences in key systems that are at risk. The risks are unevenly distributed and generally greater for disadvantaged individuals and communities, widening the gap between developed and developing countries. In the latter, climate change may cause more than 100 million people to be living in poverty by 2030, with strong impacts on mortality and morbidity (WHO, 2018). Also, according to a World Bank[30] study in the regions of Latin America, South Asia and Sub-Saharan Africa alone, the chronic impacts[31] of climate change could result in the internal migration of over 143 million people (equivalent to 2.8% of the population in these regions) by 2050 under the most pessimistic scenario. The most cited global reference is that by 2050 there could be some 200 million people displaced due to variations in rainfall regimes, droughts, sea-level rises and coastal flooding[32], although this is an area where research still needs to make much progress.

Figure 16: Magnitude and severity of consequences as a function of temperature rise (Global Adaptation Commission, 2019[33])



Source: Global Adaptation Commission, 2019, Adapt Now: A Global Call for Leadership on Climate Resilience

30. World Bank, 2018, Groundswell : Preparing for Internal Climate Migration. © World Bank. https://openknowledge.worldbank.org/handle/10986/29461
31. The chronic impacts of climate change are associated with long-term and progressive changes in climate patterns such as rising sea temperature or level.
32. https://www.osce.org/eea/14851?download=true; https://www.iom.int/news/finding-our-way-age-climate-change-and-migration;
33. Global Commission on Adaptation, 2019; Adapt Now: A Global Call for Leadership on Climate Resilience

5 CONCLUSIONS

1 | HUMAN INFLUENCE ON THE CLIMATE SYSTEM IS CLEAR

The additional emission of anthropogenic GHGs is increasing the planet's temperature with an effect that may last many millennia before natural processes are able to remove these gases from the atmosphere.

- The **atmospheric CO_2 concentration**, the GHG that contributes to over two thirds of global warming, **reached its maximum annual average of 409.8 parts per million in 2019**, above the levels observed over at least the last 800,000 years and much higher than any concentration levels that humans have ever lived with. The fifth IPCC Assessment Report (AR5) concluded with a high level of confidence that human influence through GHG emissions has been the dominant cause of warming observed since the mid-twentieth century.
- The IPCC has stated that the objectives of the Paris Agreement involve not exceeding **an atmospheric CO_2e concentration to 450 ppm (to limit temperature rise to 2°C) or 430 ppm (to 1.5°C) by the end of the century**.
- **The increase in CO_2 concentration, which is mainly due** to emissions from burning fossil fuels, accounts for three quarters of total GHG emissions (**~55.3 $GtCO_2e$ in 2018**). Between 2009 and 2018, CO_2 emissions averaged about 34.7 ± 1.8 $GtCO_2$ per year, growing at an average annual rate of 0.9% to reach a record 36.6 $GtCO_2$ in 2018 (+2% compared to 2017).

2 | THE SCIENTIFIC EVIDENCE SHOWS THAT CLIMATE CHANGE IS A REALITY

It finds that its effects are occurring at an unprecedented rate and with observable consequences.

- **Global temperatures have been rising steadily since 1880**, with 19 of the hottest 20 years since records began having occurred since 2001. Thus, 2019 was the second warmest year on record, with an average global surface temperature that exceeded that of the pre-industrial era (1850-1900) by ~1.1°C, with a greater increase over land than over the ocean. Since the 1980s, each successive decade has been warmer than every previous one, with continuous warming in the range of 0.1°C to 0.3°C per decade (WMO, 2020). The consequences of this global warming are being seen in other variables such as the decline in the ice layer, the acidification and deoxygenation of the oceans and the rise in sea levels.
- There is **also a relationship between global warming and extreme weather events (heatwaves, cyclones, etc.)**. Despite the complexity of their study, since they are by definition rare/exceptional, there is a general consensus that changes in the frequency or intensity of these extreme weather events are increasing in many regions as a result of global climate change.

3 | CLIMATE CHANGE AFFECTS ALL SECTORS OF ACTIVITY

Climate change, and particularly extreme events, greatly affect human well-being and all sectors of activity, both directly and indirectly, through their impacts on natural ecosystems and socio-economic systems.

4 CLIMATE CHANGE WILL REQUIRE ADAPTATION ACTION

There is a certain degree of climate change that is inevitable, and this will require adaptation action.

- Due to the emissions accumulated until now, the inertia of the climate system and the current rate of emissions, the physical effects of climate change are similar for all predicted emission scenarios in the short term with the 1.5°C limit expected to be reached around 2040 (IPCC SR15, 2018), if current warming rates are maintained.
- A great variation in the predicted physical results arises after 2050, depending on the actions taken in the coming decades, so that, if global climate neutrality is achieved by 2050, the increase in global temperature could remain at 1.5°C in 2100. However, the stabilisation of the global average surface temperature does not imply the stabilisation of all aspects of the climate system, and some aspects (such as sea level rise) will continue for centuries as they respond more slowly to changes in global temperature. **Adaptation actions are therefore key.**

5 THE INCREASE OF EVERY TENTH OF A DEGREE IN TEMPERATURE

However, every tenth of a degree in temperature rise is important as impacts increase rapidly, even exponentially, so mitigation is key. The more the climate is disturbed, the greater the risk of severe, widespread and irreversible impacts on ecological and human systems. Limiting the temperature increase to 1.5°C by 2100 is still possible and would substantially reduce the magnitude of many impacts even when compared to a 2°C temperature increase scenario.

6 EFFORTS TO REDUCE EMISSIONS WILL HAVE AN IMPACT ON THE GLOBAL CLIMATE

Global efforts to reduce emissions in the coming decades will have a profound impact on the global climate in the second half of this century. These **mitigation efforts will need to be accompanied by actions to adapt** to the changing conditions to address the challenge.

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Offshore wind farm West of Duddon Sand

Iberdrola and its commitment with an ambitious and urgent climate action

More than two decades ago, Iberdrola understood the significance of climate change. The company then began a profound transformation of its business model, which has allowed it to lead the energy transition and contribute to moving towards a sustainable and fair future.

The electricity sector plays a key role in fulfilling the goal set by the historic Paris Agreement to keep global temperature rise well below 2 °C. The Iberdrola group, an active participant in the different Climate Summits, is fully aligned with this international pact, having assumed a public commitment to achieve carbon neutrality by 2050. Reaching a decarbonised energy model is currently feasible and can be achieved efficiently and competitively. Iberdrola is in an optimal position to manage the risks and take advantage of opportunities offered by this energy transition thanks to its leadership in renewable energy, smart grids, storage and digitisation.

Aware that climate change is a challenge that requires the active participation of all agents of society, the Iberdrola group carries out different awareness-raising initiatives within the framework of its Social Awareness Plan on Climate Change. This document is part of our initiative to make educational materials available to society to raise awareness about global climate change.

Find out more about our climate action and awareness-raising activities on our website, where you can find materials to further explore this great global challenge:

QR access to Iberdrola´s website on climate change

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