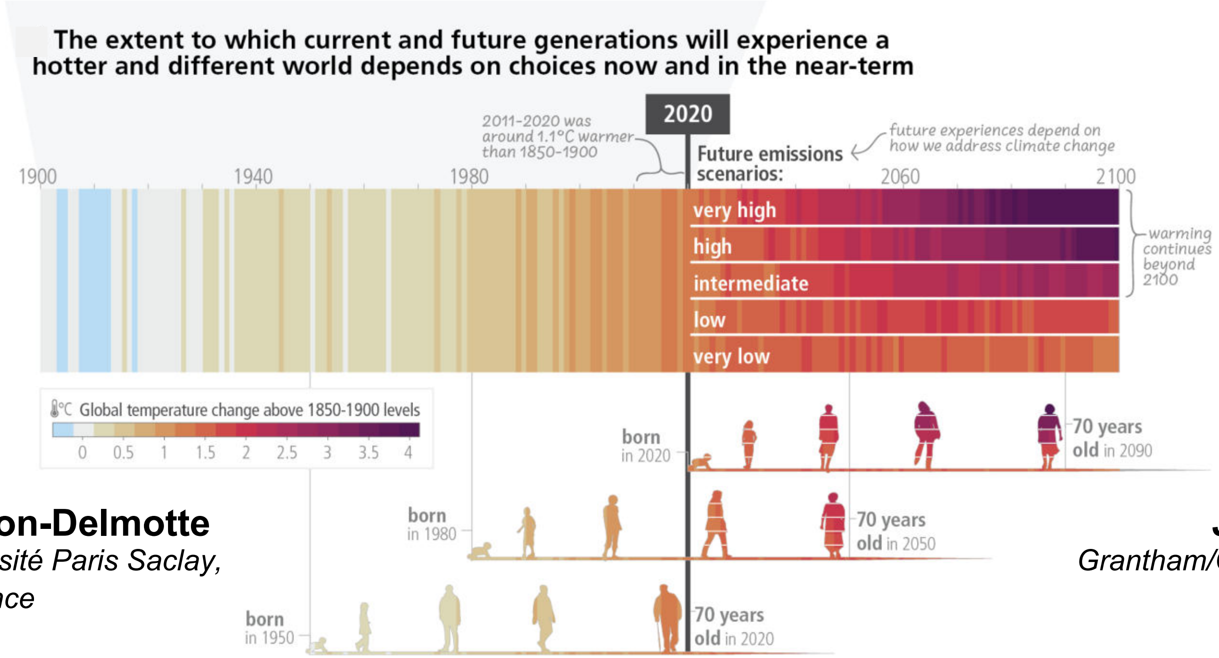
European Geoscience Union
GIFT - Geoscience Information for Teachers

Climate emergency, human agency : making sense of the current state of scientific knowledge on climate change to strengthen climate literacy



Valérie Masson-Delmotte
IPSL/LSCE, Université Paris Saclay, France

Joeri Rogelj
Grantham/CEP, Imperial College, UK
IIASA, Austria

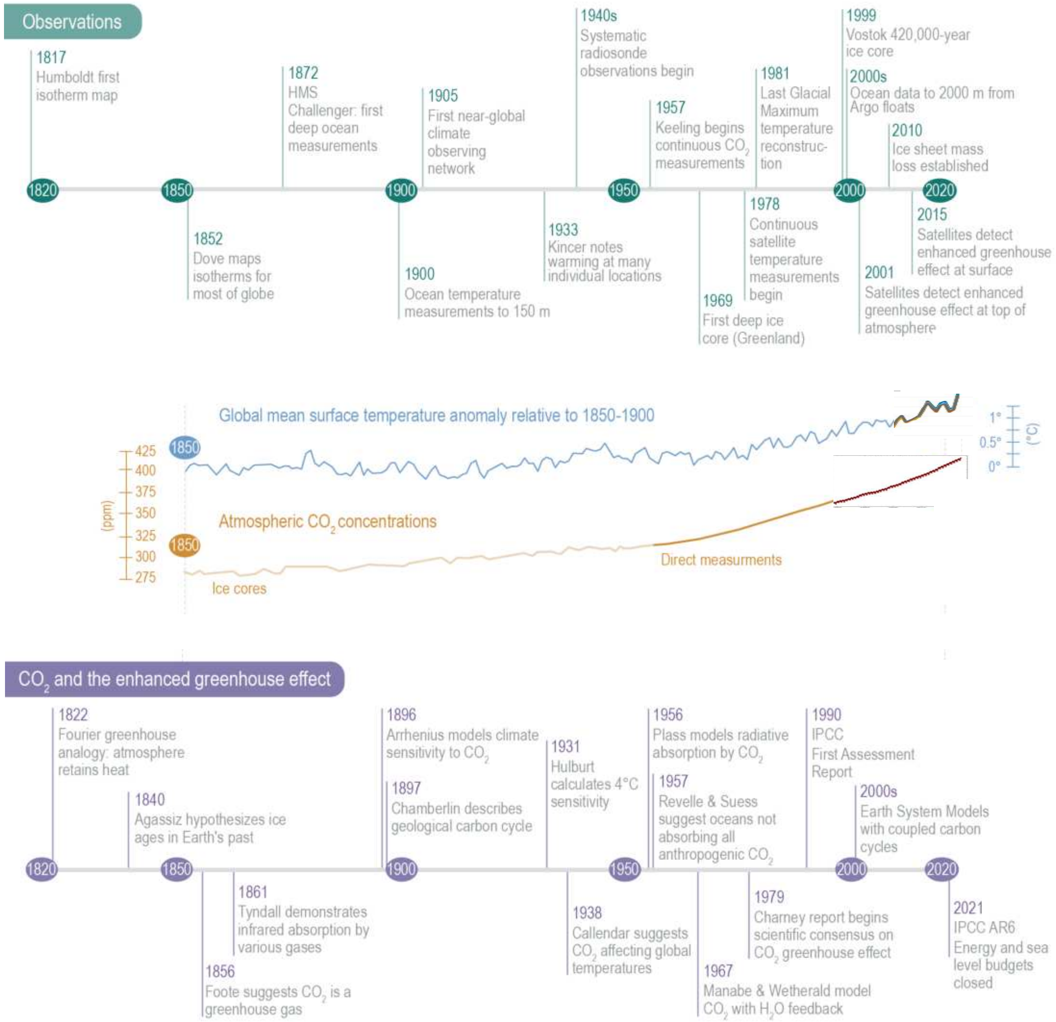
https://www.ipcc.ch/report/ar6/syr/

Climate literacy encompasses being aware of climate change, its anthropogenic causes and implications

Systemic barriers to climate action include the lack of climate literacy

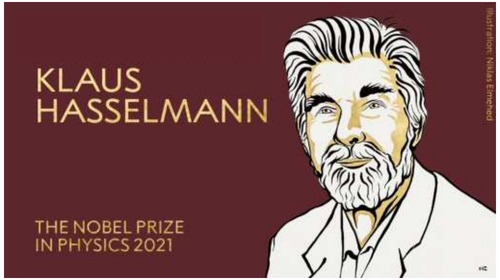
Human influence on climate : where are we now?


Climate science milestones



https://www.ipcc.ch/report/ar6/wg1/figures/chapter-1/figure-1-6/
+ WMO 2024 + NOAA 2024

Attribution



Process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence

Avoided emissions (mitigation) and avoided impacts (adaptation) resulting from climate action

Human activities, emissions and concentrations, and **human influence on the Earth's radiative forcing**

Observed global or regional trends and events, natural climate variability and **human influence on climate**

Observed impacts resulting from climatic impact-drivers (impact attribution)

Cross-Working Group Box on Attribution in IPCC AR6

Climate action is gaining momentum

Steady decrease of greenhouse gas emissions in more than 18 countries

More than half of global greenhouse gas emissions in the scope of public policies

Progress in adaptation planning and implementation, but fragmented and incremental responses, limits, growing adaptation gaps and evidence of maladaptation

Insufficient financial flows

Public policies have prevented several billion tons of CO_2-equivalent emissions each year

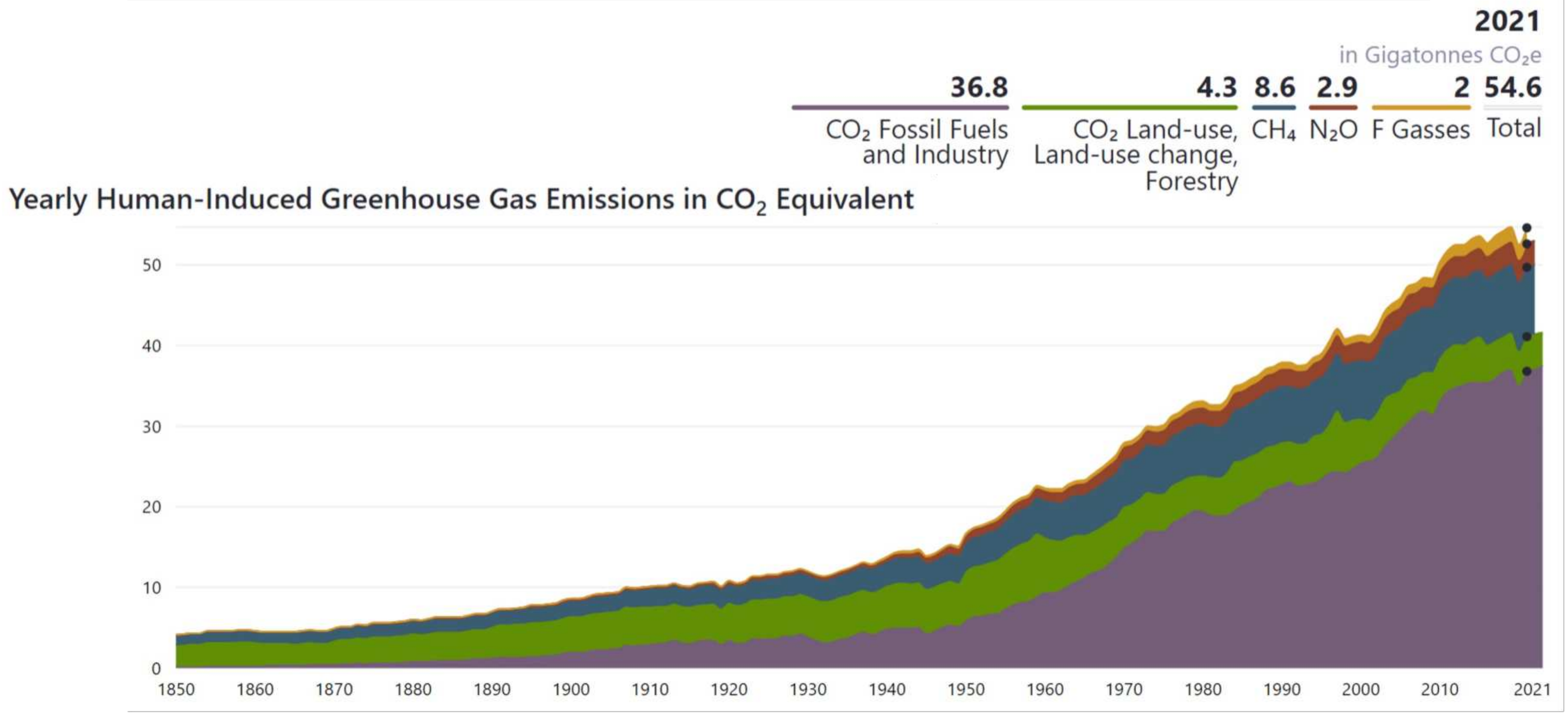
Renewable energies, batteries : decrease in costs, increases in installed capacities

Energy efficiency, demand management, reduction of food waste : affordable, high acceptability

Greening of cities, slowing of global net deforestation

but the pace and scale of what has been done so far, and current plans, are not sufficient to limit the escalation of climate risks

Greenhouse gas emissions continue to increase, with unequal historical and ongoing contributions



ESSD - Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence

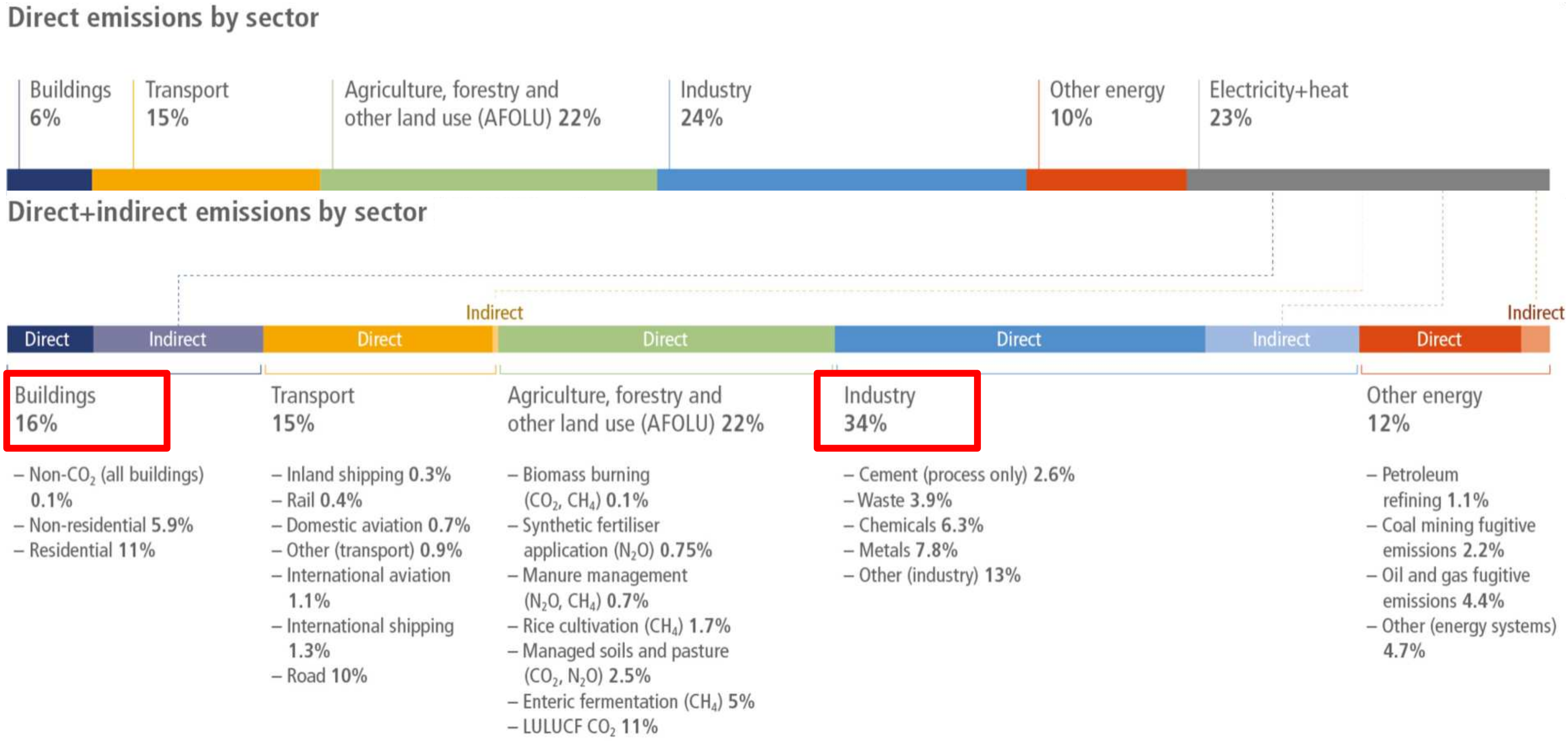
ClimateChangeTracker.org

Which activities contribute most to global greenhouse gas emissions?

Direct emissions by sector

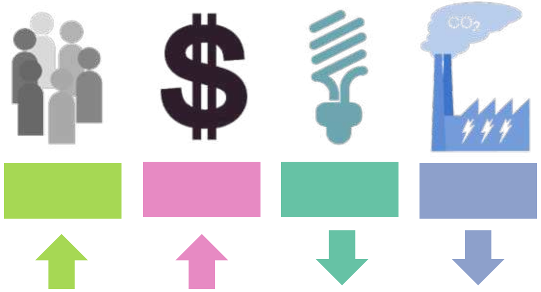
Source: IPCC AR6 WG3 Figure 2.11

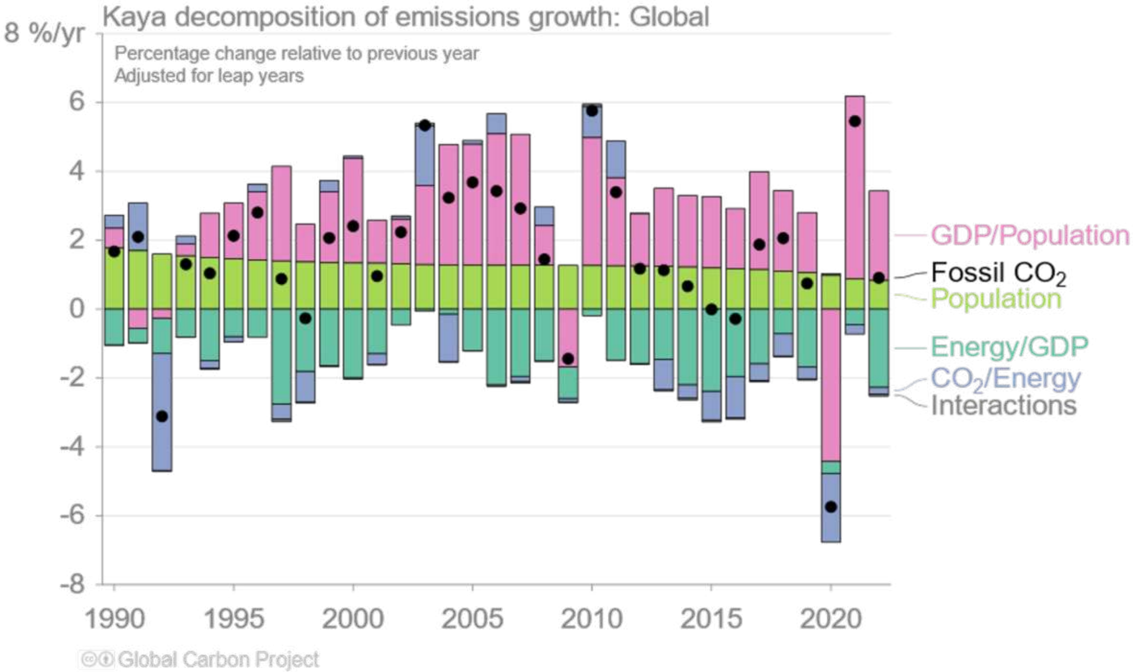
Which activities contribute most to global greenhouse gas emissions?



What makes CO_2 emissions increase or decrease?

Decarbonisation of energy and energy efficiency are largely responsible for the reduced growth in CO_2 emissions over the last decade



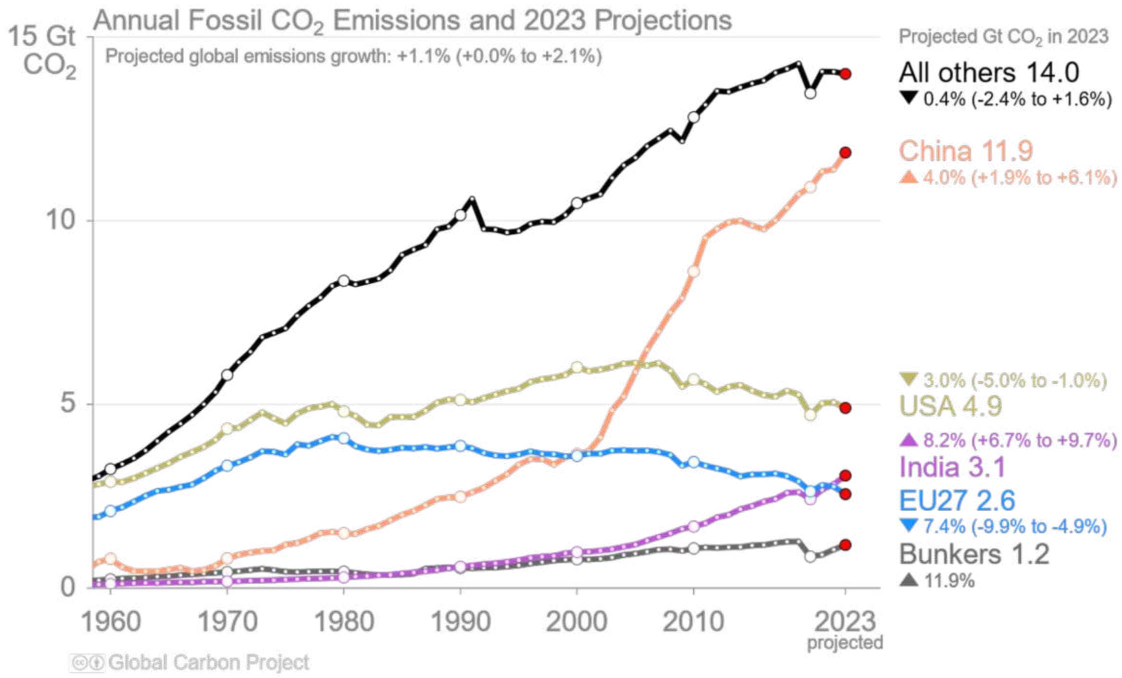


ESSD - Global Carbon Budget 2023

GLOBAL CARBON project

Sharp contrast in trends for top emitters in 2023

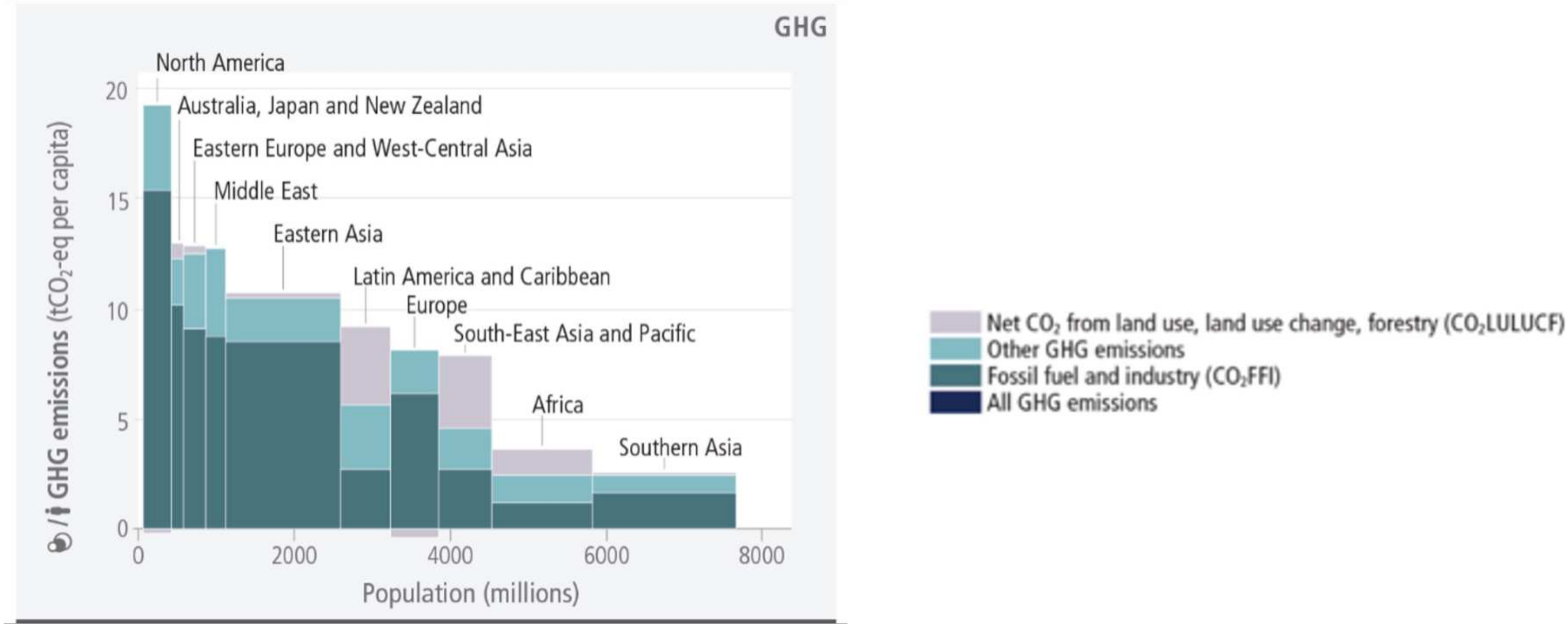
EU: -7.4%
USA: -3.0%
India: +8.2%
China: +4.0%



ESSD - Global Carbon Budget 2023

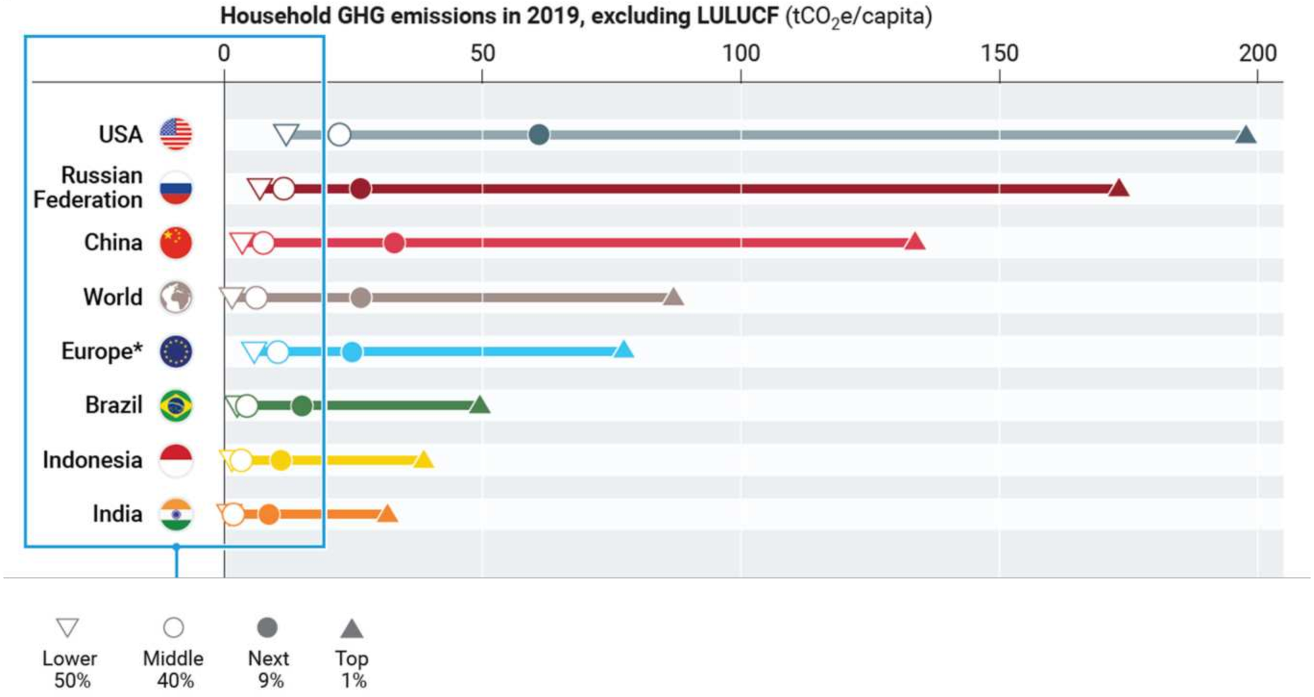
GLOBAL CARBON project

Strong differences in regional contributions per capita



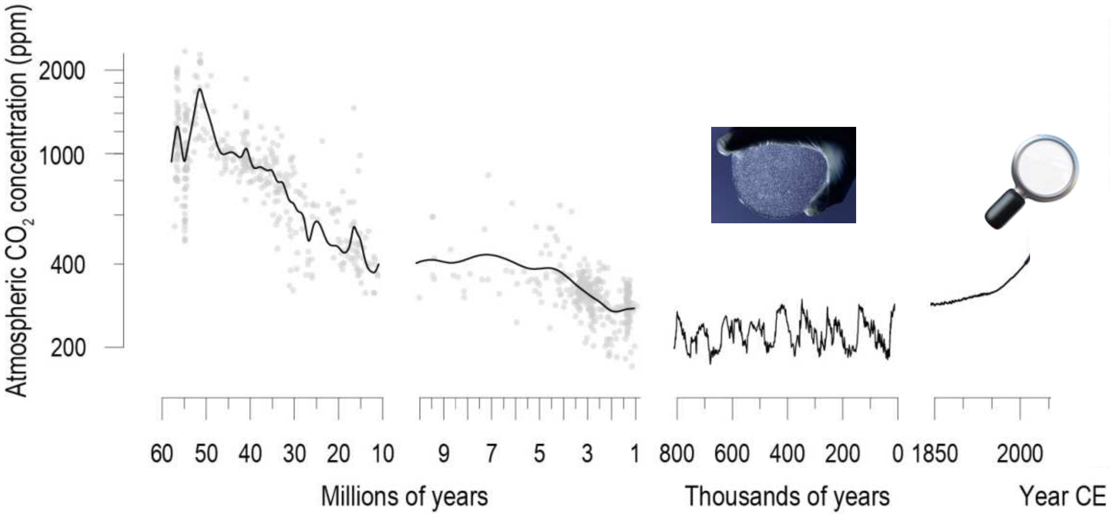
Source: IPCC AR6 SYR Figure 2.2

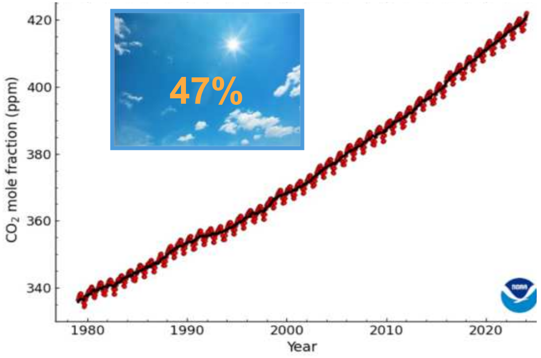
Stark emission inequalities between and within countries



Source: Emissions Gap Report (2023) – Figure 2.4

Greenhouse gas concentrations continue to increase in the atmosphere





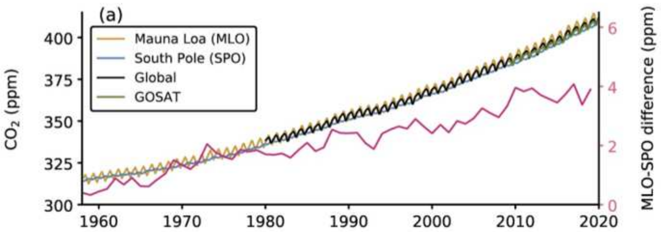
Fate of CO_2 emissions

Current CO_2 level 50% above pre-industrial level
Unprecedented in more than 2 million years
10 x faster / past 800 000 years
4-5x+ faster / past 56 millions d'années

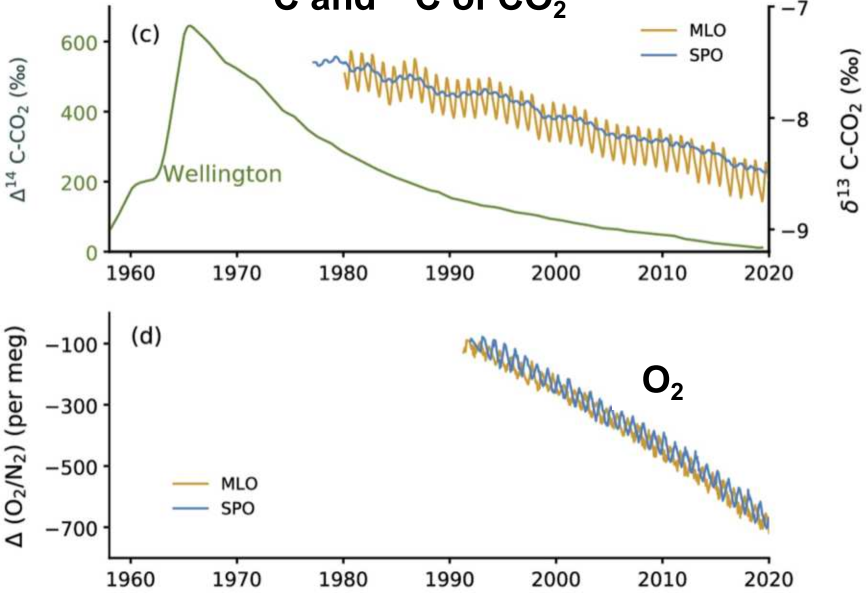
IPCC WGI TS ; Updates : Global Carbon Budget 2023; NOAA 2024

Atmospheric greenhouse gas concentration increase during the industrial era is unequivocally due to human activities

Inter-hemispheric **CO_2 gradient**



^{13}C and ^{14}C of CO_2

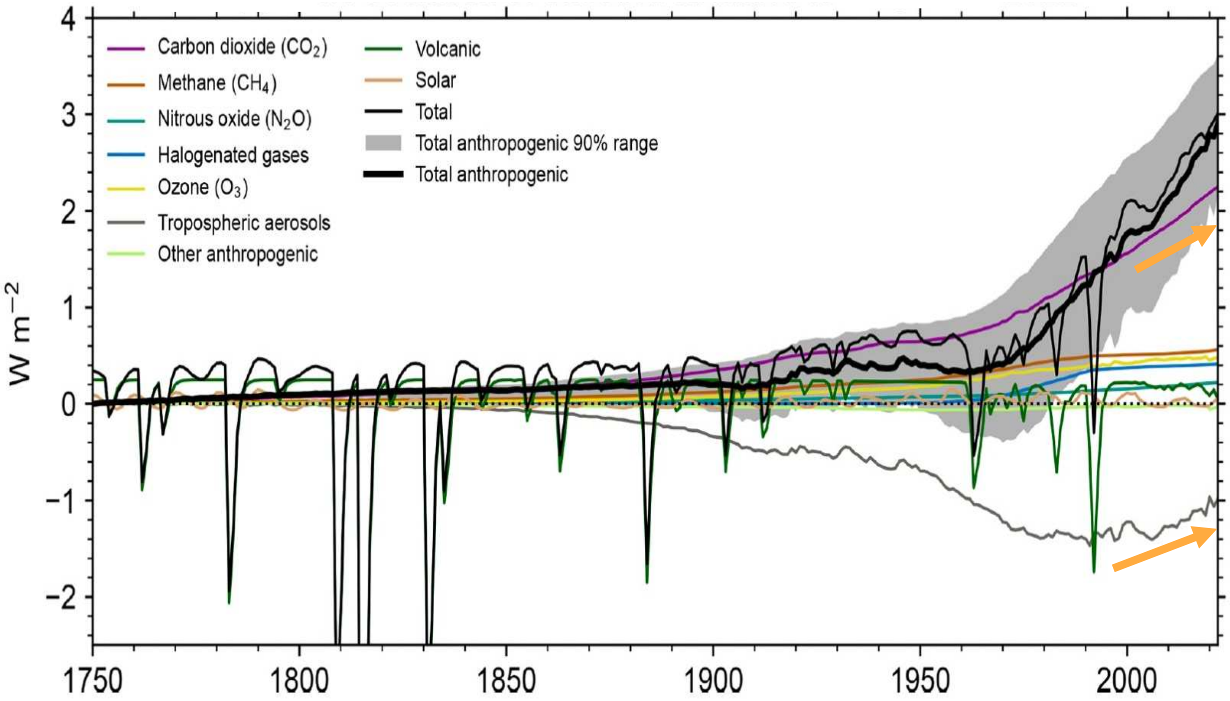


The additional CO_2 in the atmosphere is:

- very old
- originally from plants
- resulting from a combustion process
- predominantly emitted in the Northern Hemisphere

IPCC AR6 WG1 Figure 5.6

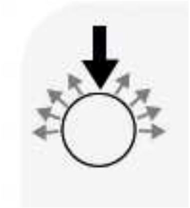
Radiative forcing increases due to increases in heat-trapping greenhouse gases and reduced aerosol ⛱️ effect

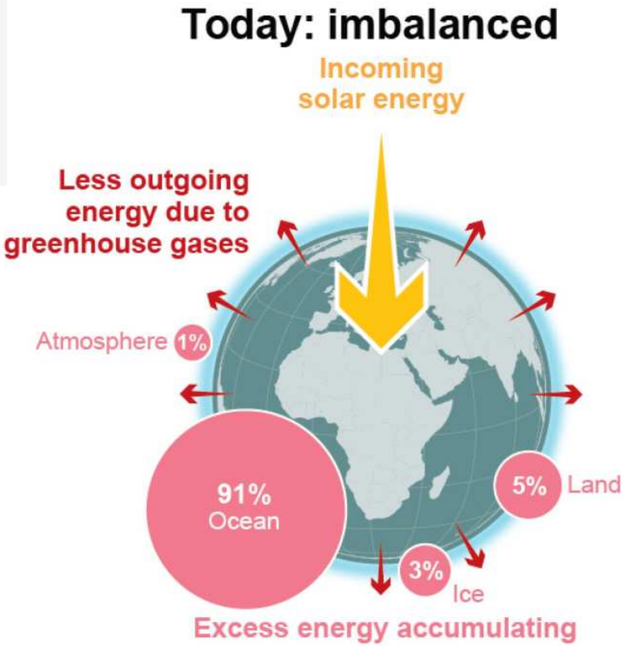


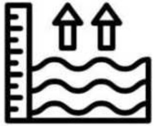
🔍 Highest decadal increasing rate

Update up to 2022 from Forster et al ESSD (2022)

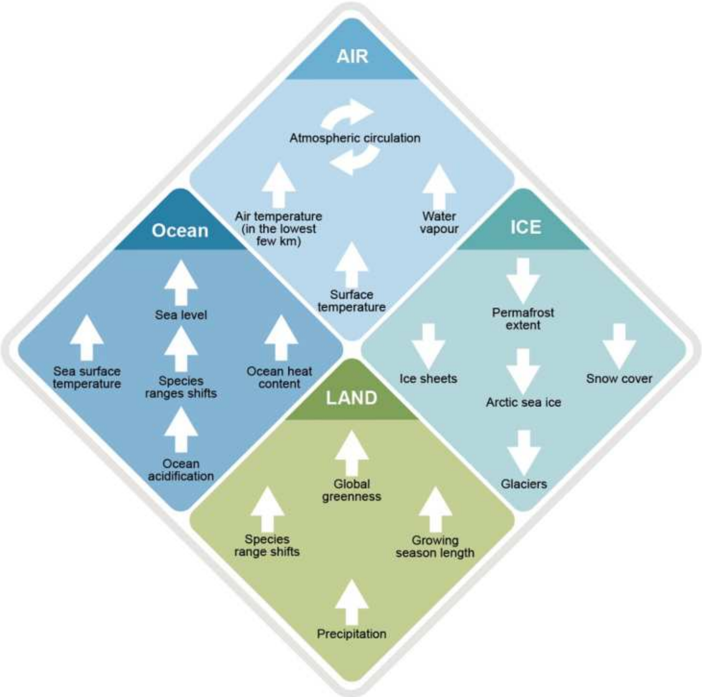
Heating of the climate system causes widespread, rapid and intensifying changes







Acceleration
of sea level rise



IPCC WGI 2021 FAQs

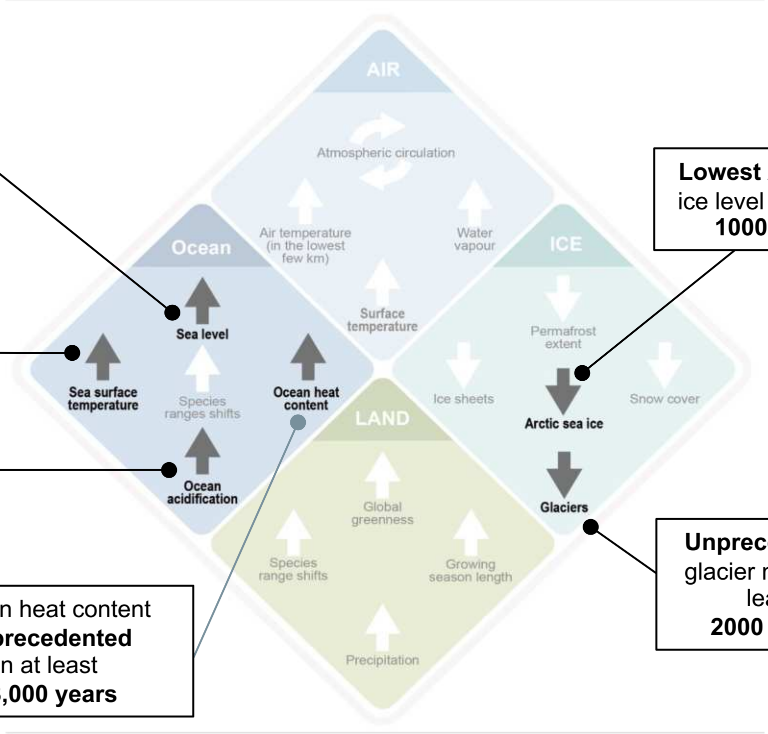
Observed changes are unprecedented in thousands of years

Fastest sea level rates in at least **3000 years**

Fastest sea surface temperature warming in at least **11,000 years**

Ocean acidification **unusual** in at least **2 million years**

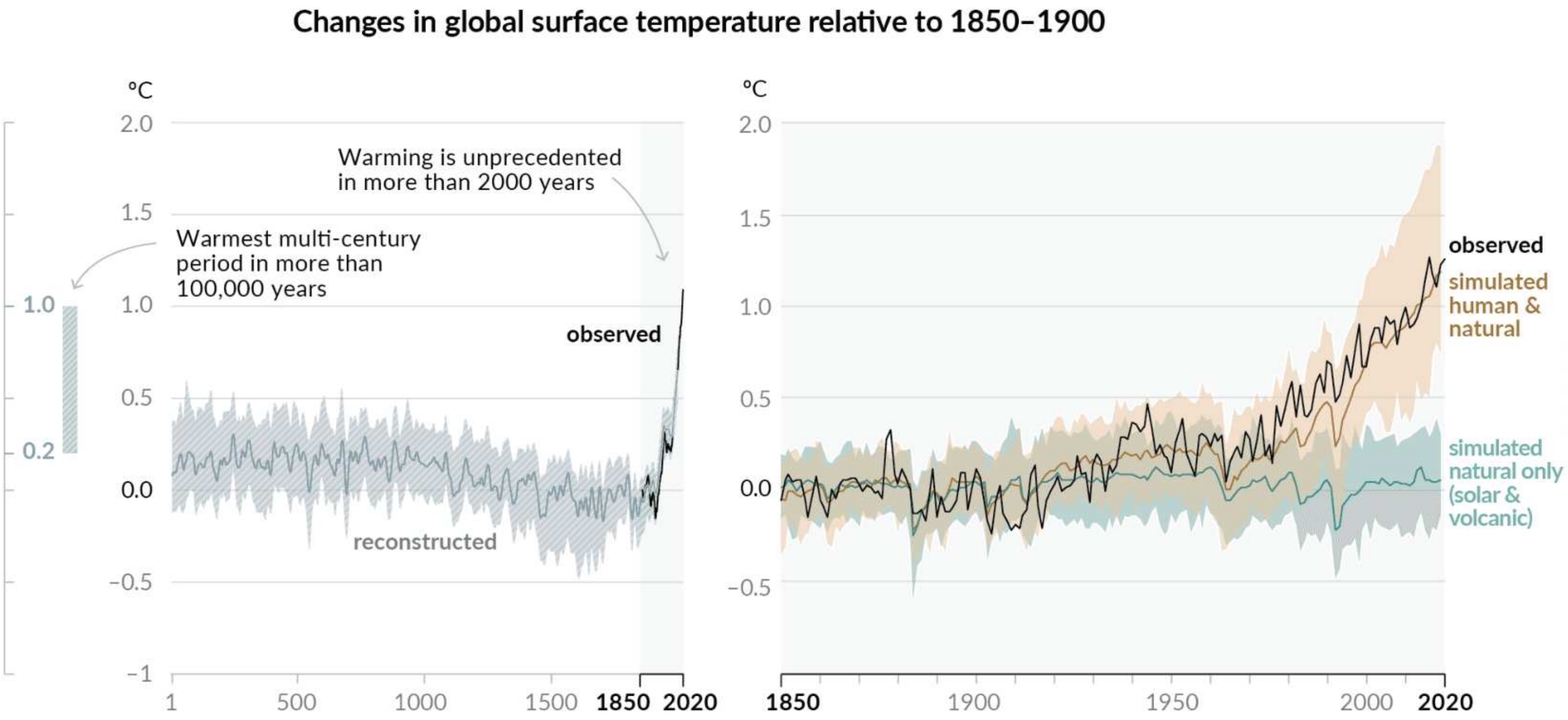
Ocean heat content **unprecedented** in at least **18,000 years**



Lowest Arctic sea ice level in at least **1000 years**

Unprecedented glacier melt in at least **2000 years**

Observed changes are unprecedented in thousands of years

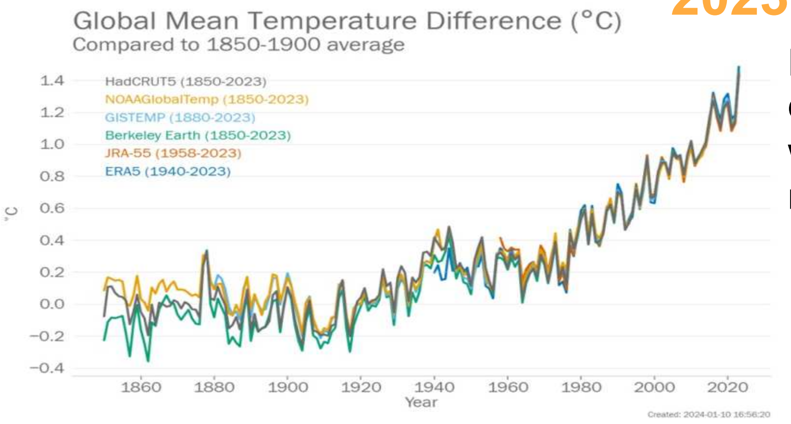


IPCC WGI 2021 SPM

Human activities have unequivocally caused global warming

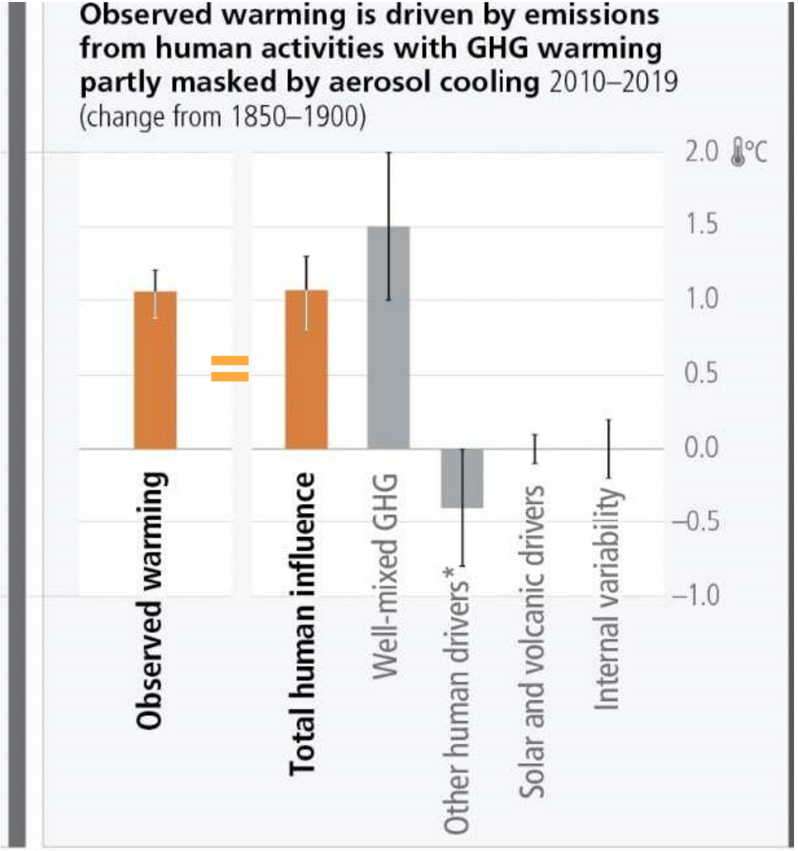
Latest decade
+1.2°C / 1850-1900

2023



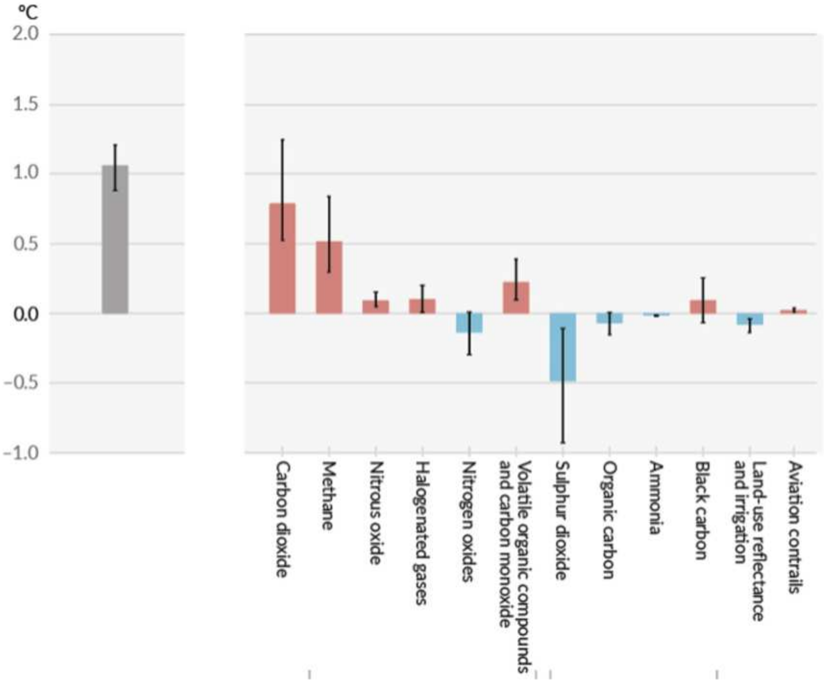
Highest decadal warming rate

+ modulations by natural variability



IPCC SYR updated up to 2022 from Forster et al ESSD (2022) and WMO State of Climate (2024)

Improved understanding of each aspect of human influence



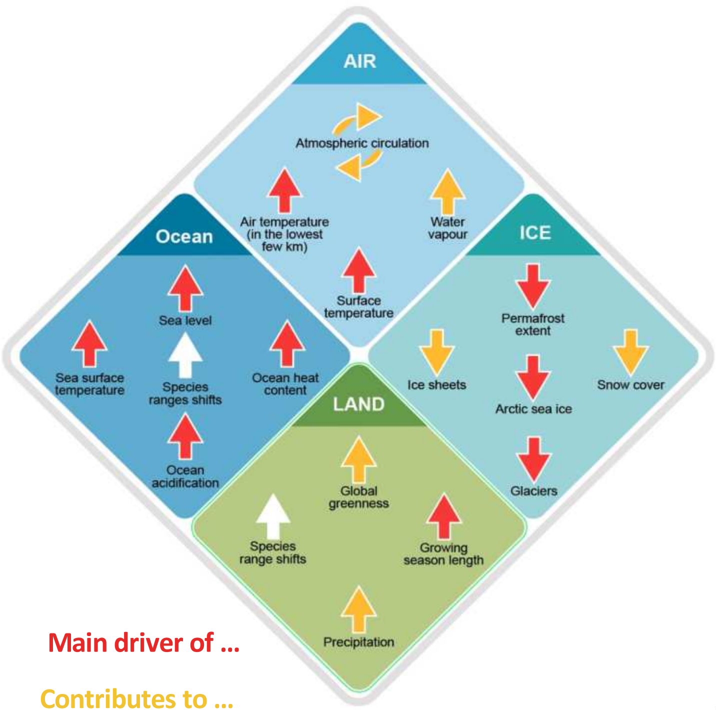
Mainly contribute to changes in **non-CO_2 greenhouse gases**

Mainly contribute to changes in **anthropogenic aerosols**

Evidence from radiative forcing and climate sensitivity studies

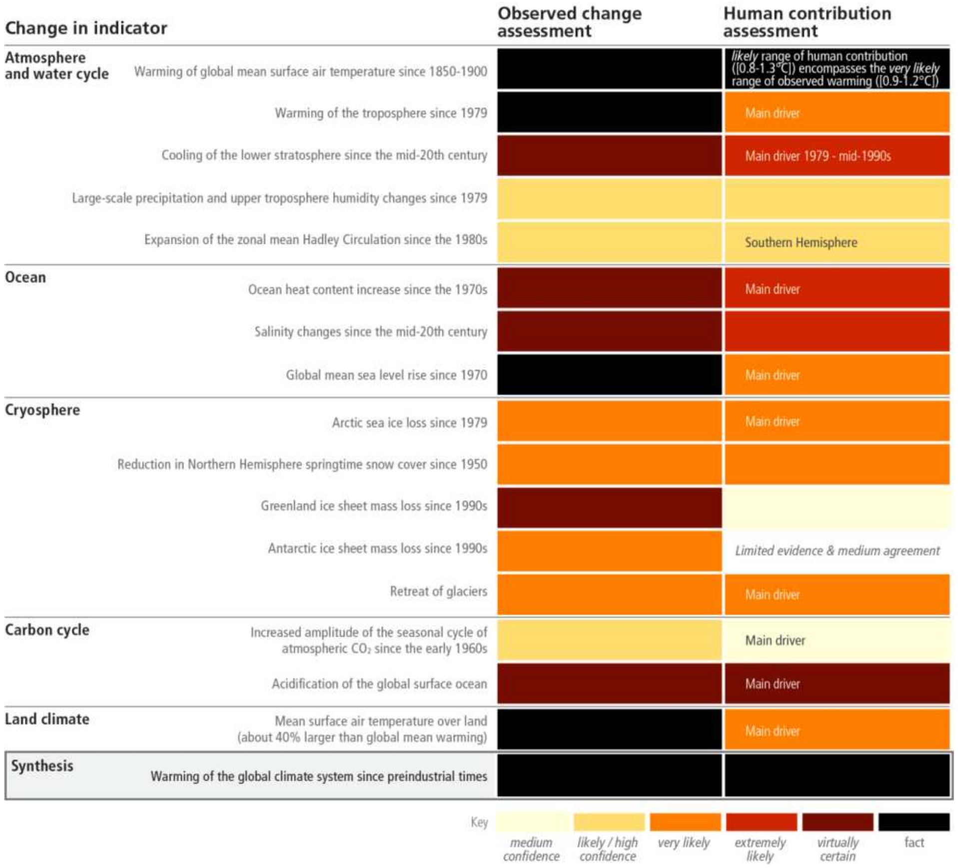
IPCC WGI 2021 SPM

Human influence on the climate system is an established fact



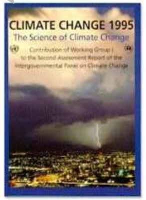
Main driver of …

Contributes to …



Human influence on the climate system

1990 : it is certain than greenhouse gases are increasing in the atmosphere because of **human activity**



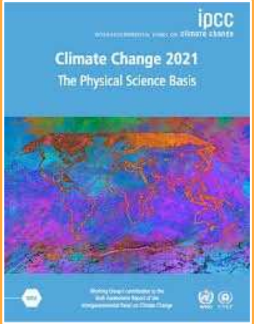
1995 : **discernable** human influence on the global climate

2001 : **most of warming** seen over the previous 50 years was due to human activity

2007 : warming of the climate system is **unequivocal**

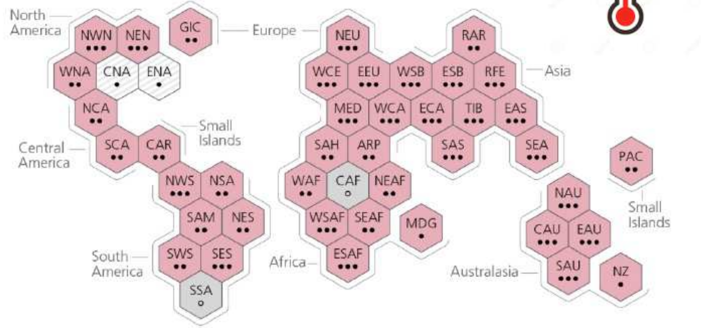
2013: human influence on the climate system is **clear**

2021: human activities have unequivocally caused global warming

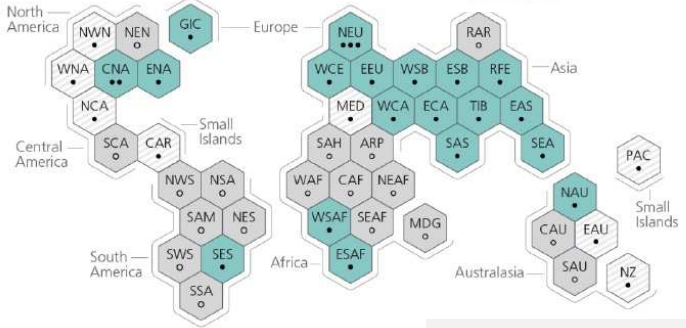


Human-caused climate change increases the frequency and severity of extreme events

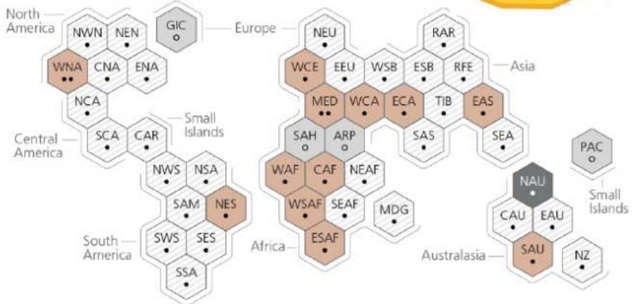
Hot extremes



Heavy rainfall

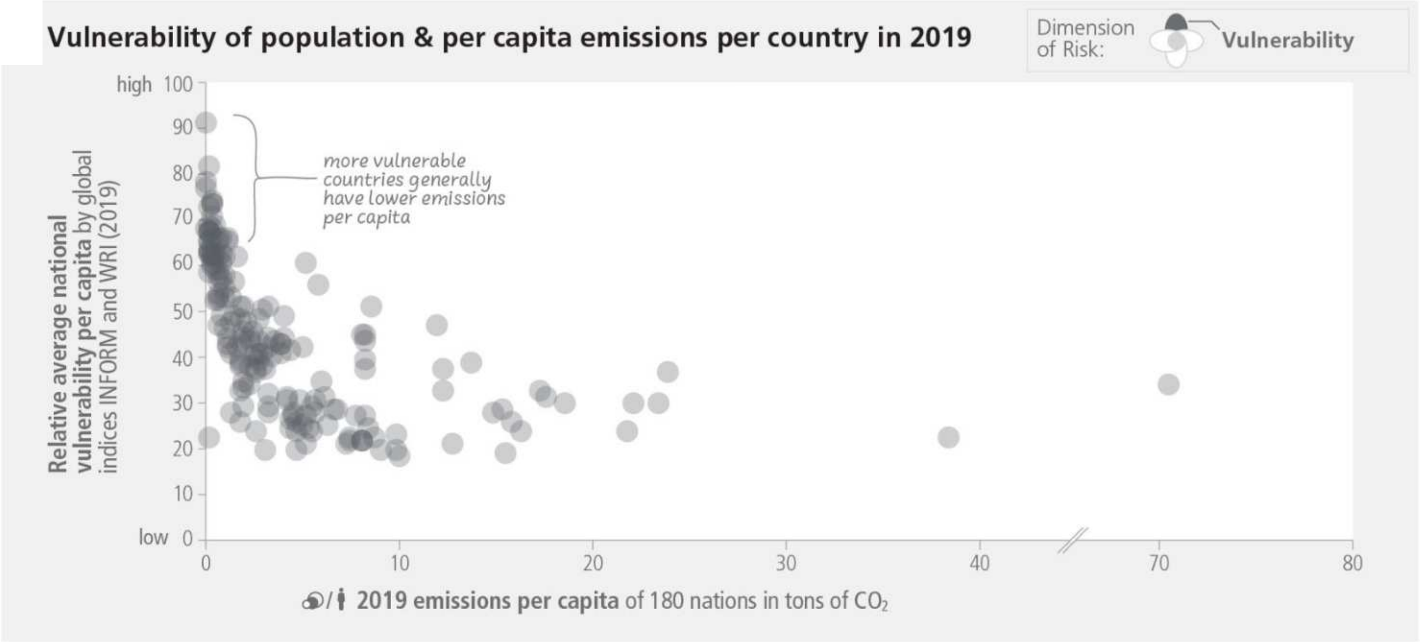


Agricultural drought



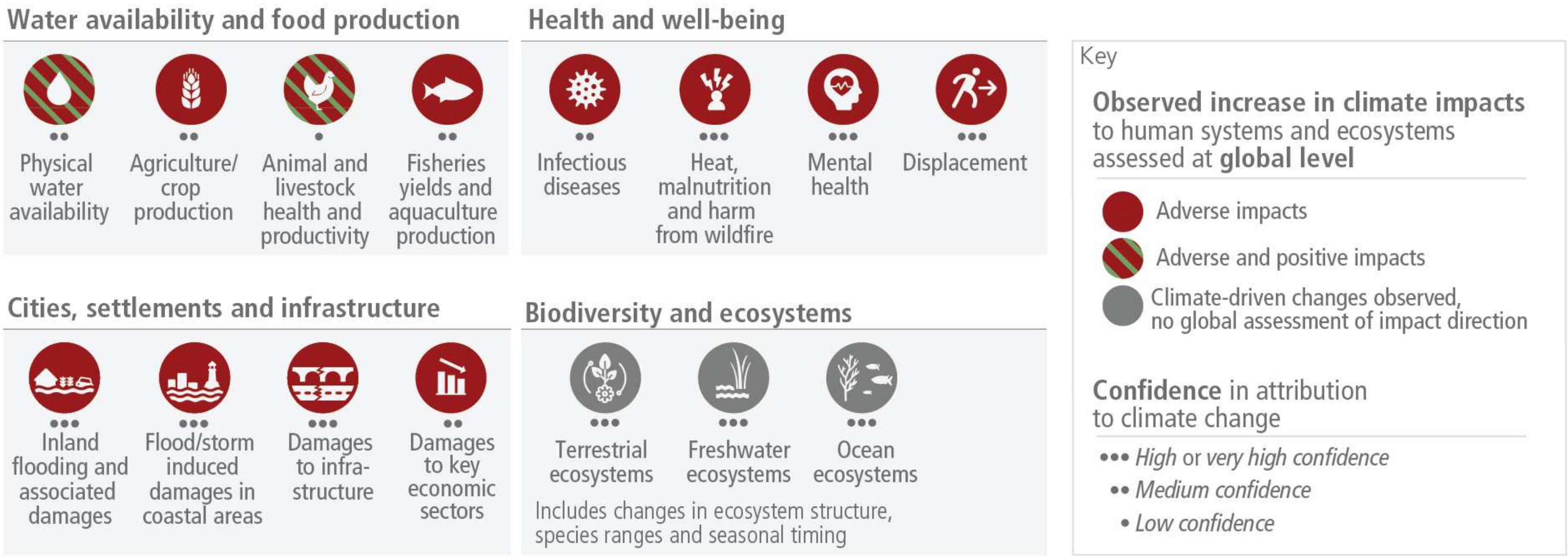
For recent events : https://www.worldweatherattribution.org

Vulnerable communities who have least contributed to climate change are disproportionately affected

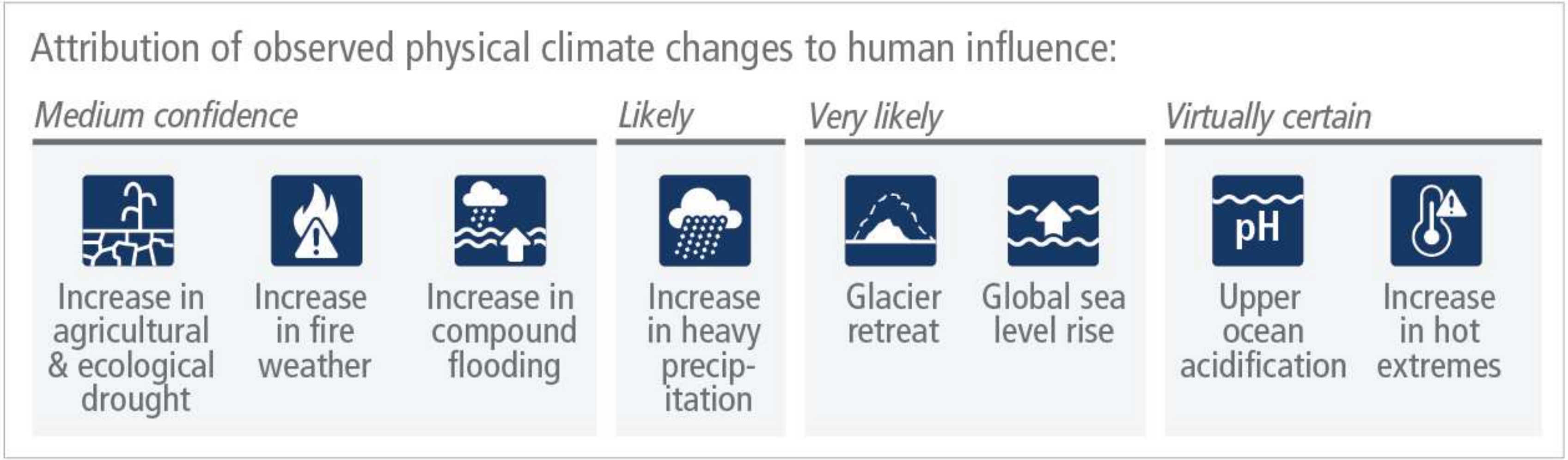


⚠️ 3.3 to 3.6 billion people live in highly vulnerable contexts

Widespread and substantial impacts and related losses and damages are attributed to climate change



Impacts are driven by changes in multiple physical climate conditions attributed to human influence

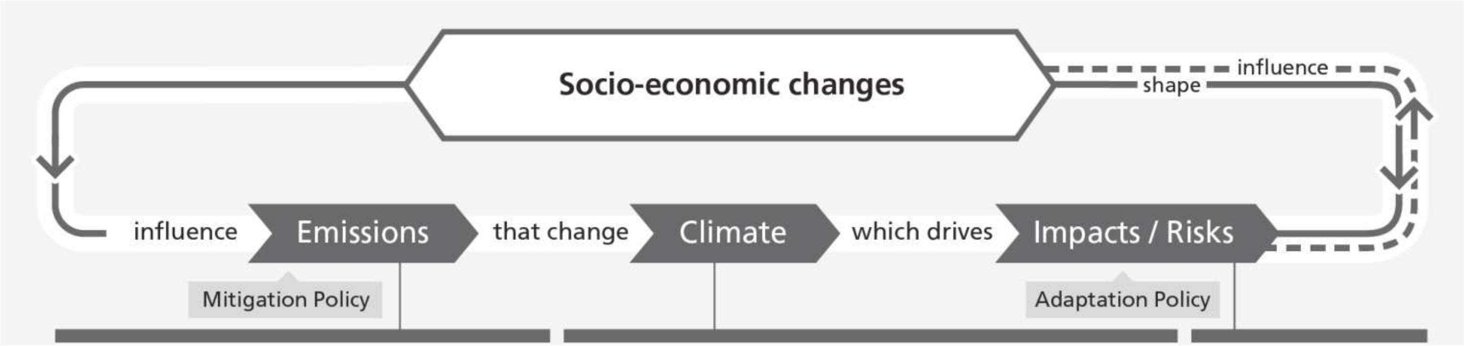


every increment of future global warming will increase changes in these climatic impact-drivers

Climatic impact-driver framework, Ruane et al, Earth's Future (2022)

What are future climate risks?

Cause – effect chain : scenarios, emissions, global warming levels, climate change and risks



climate and carbon cycle feedbacks

Equilibrium climate sensitivity (ECS)

The equilibrium (steady state) change in the surface temperature following a doubling of the atmospheric carbon dioxide (CO_2) concentration from pre-industrial conditions

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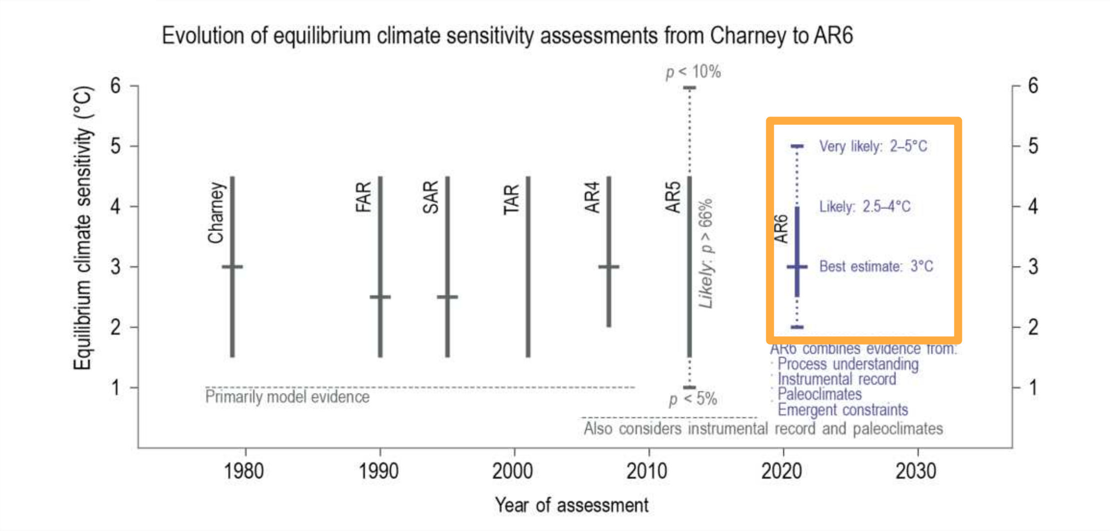
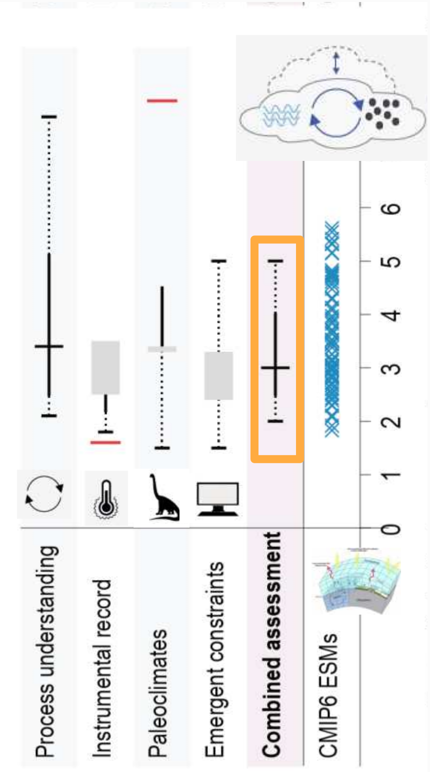
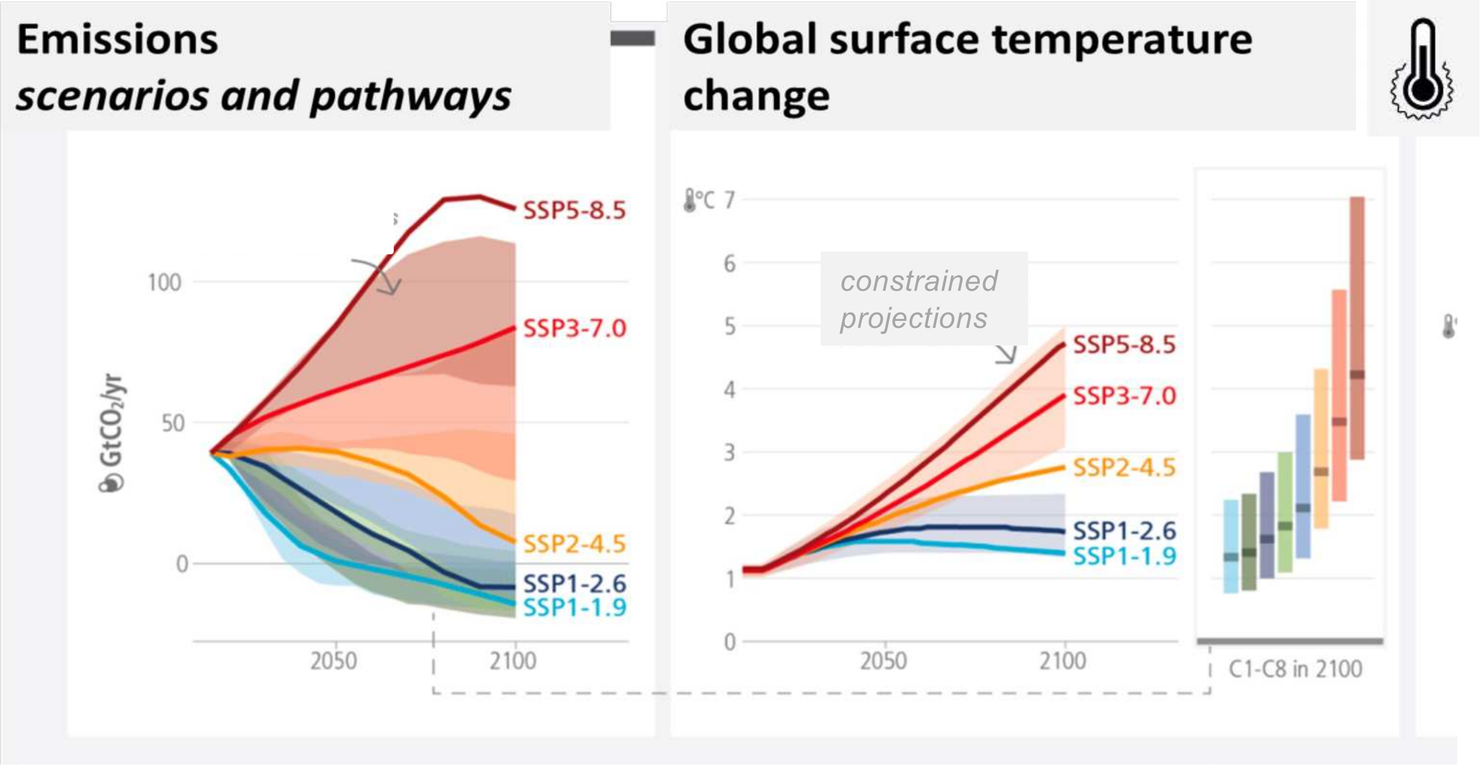




Future warming depends on future emissions

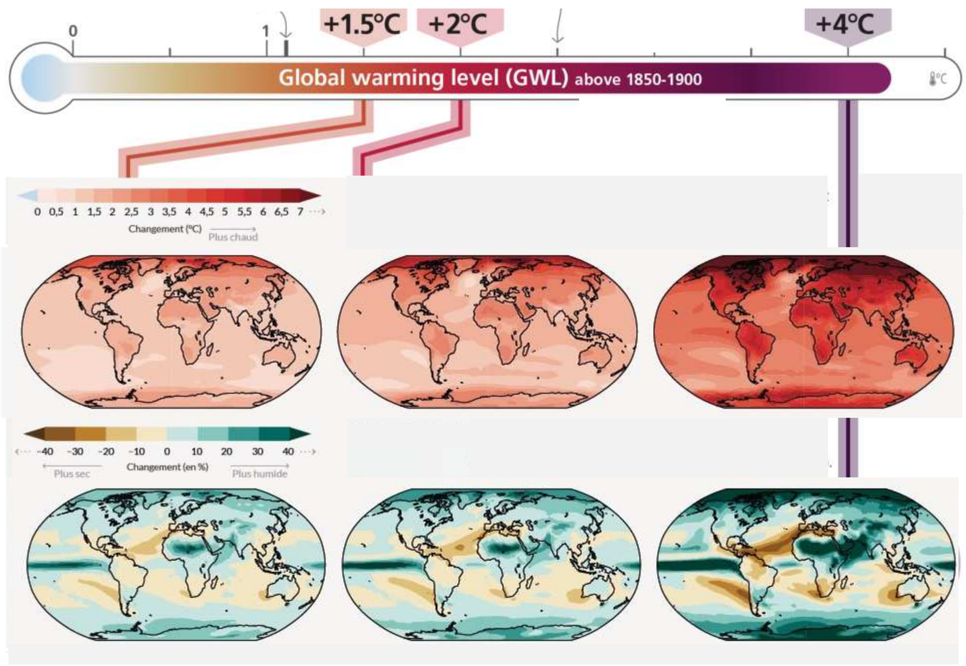


If emissions are strongly reduced, discernable effects within 20 years

+ short-lived forcers (net effect methane + aerosols)

+ modulations by natural variability

With every increment of global warming, regional changes in mean climate become more widespread and pronounced



Change in annual mean temperature

Change in annual mean precipitation

Water cycle : more intense, more variable

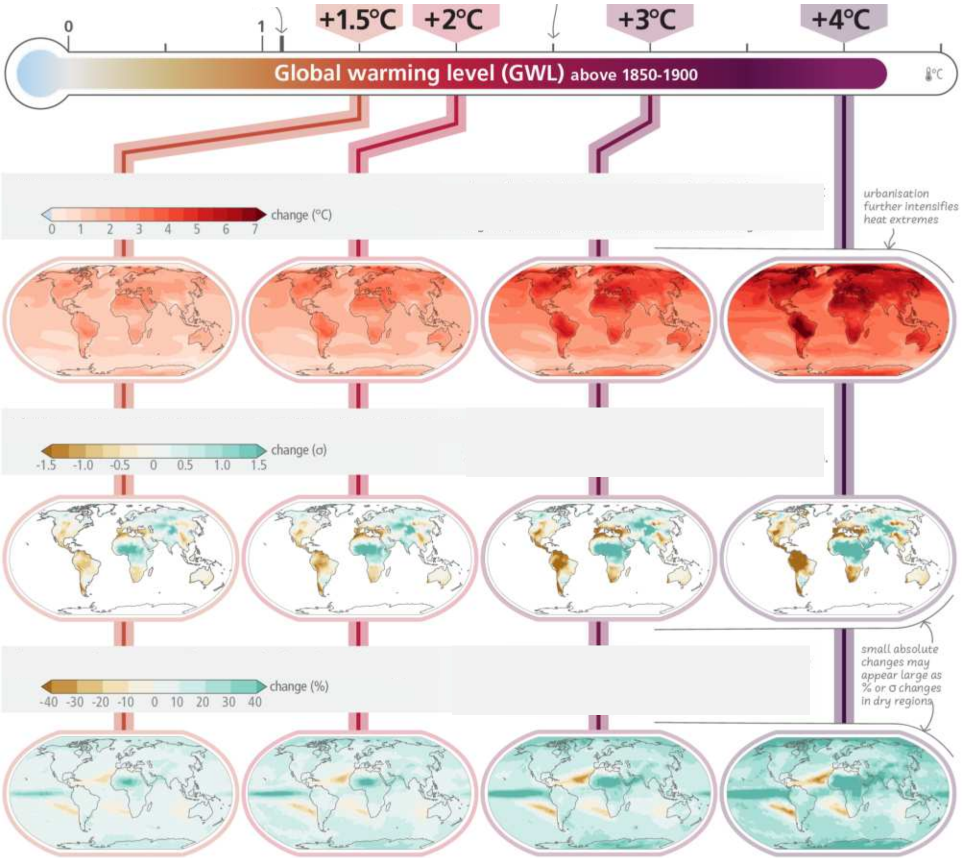
https://interactive-atlas.ipcc.ch/

With every increment of global warming, regional changes in climatic impact-drivers become more widespread and pronounced

Change in hottest day temperature (°C)

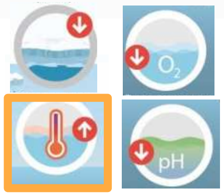
Change in annual mean soil moisture (sd)

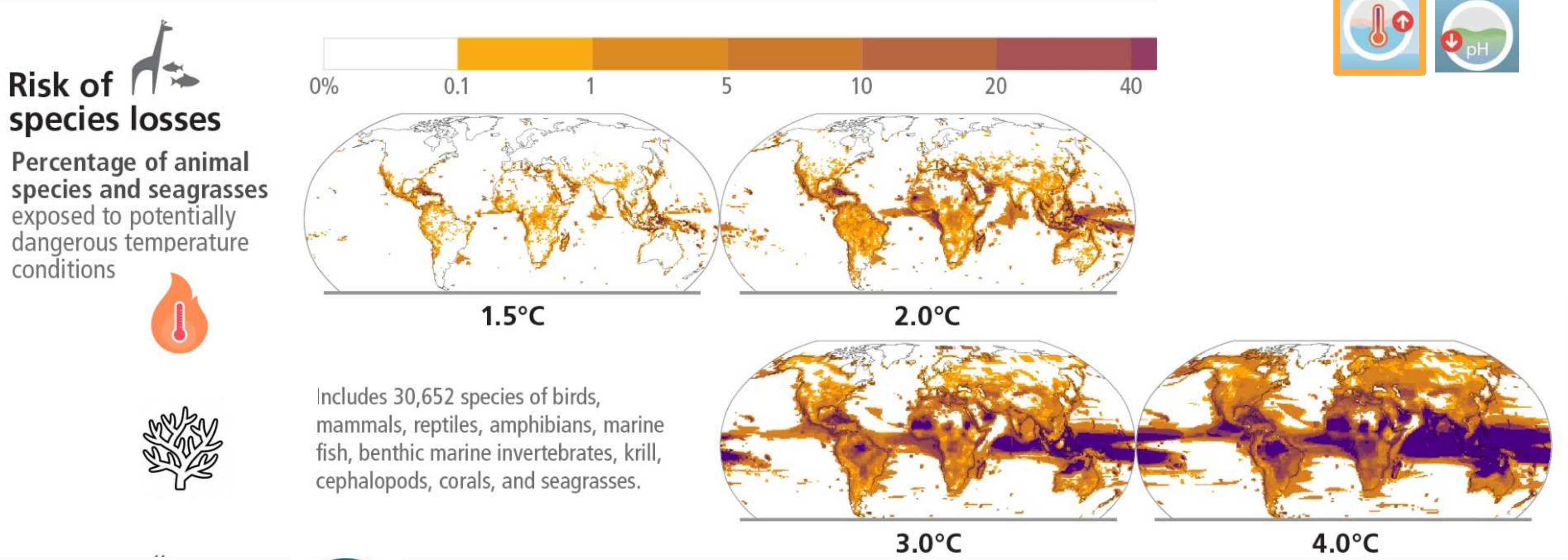
Change in wettest day precipitation (%)



Transformative adaptation

Key risks : ecosystems and biodiversity

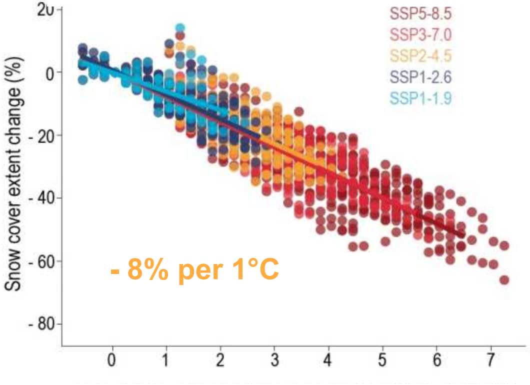




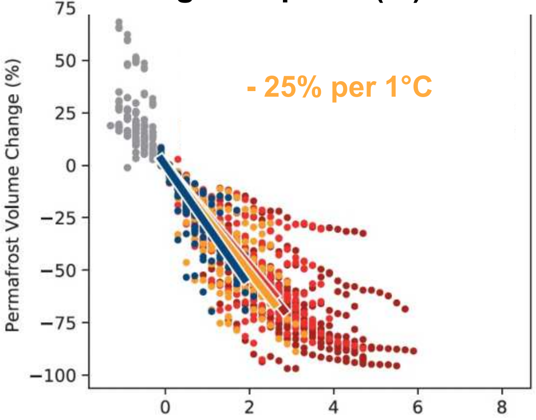
Protect ecosystems, reduce other pressures

With every increment of global warming, cryosphere loss becomes more widespread and pronounced

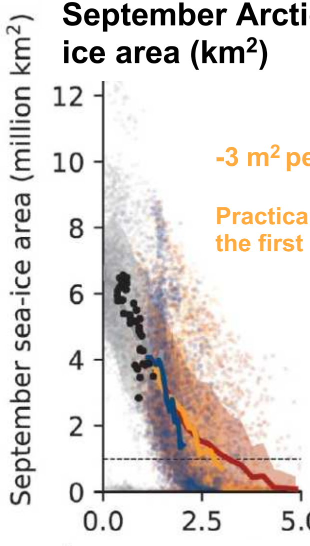
Northern Hemisphere March-May snow cover change (%)



Global permafrost volume change - top 3 m (%)



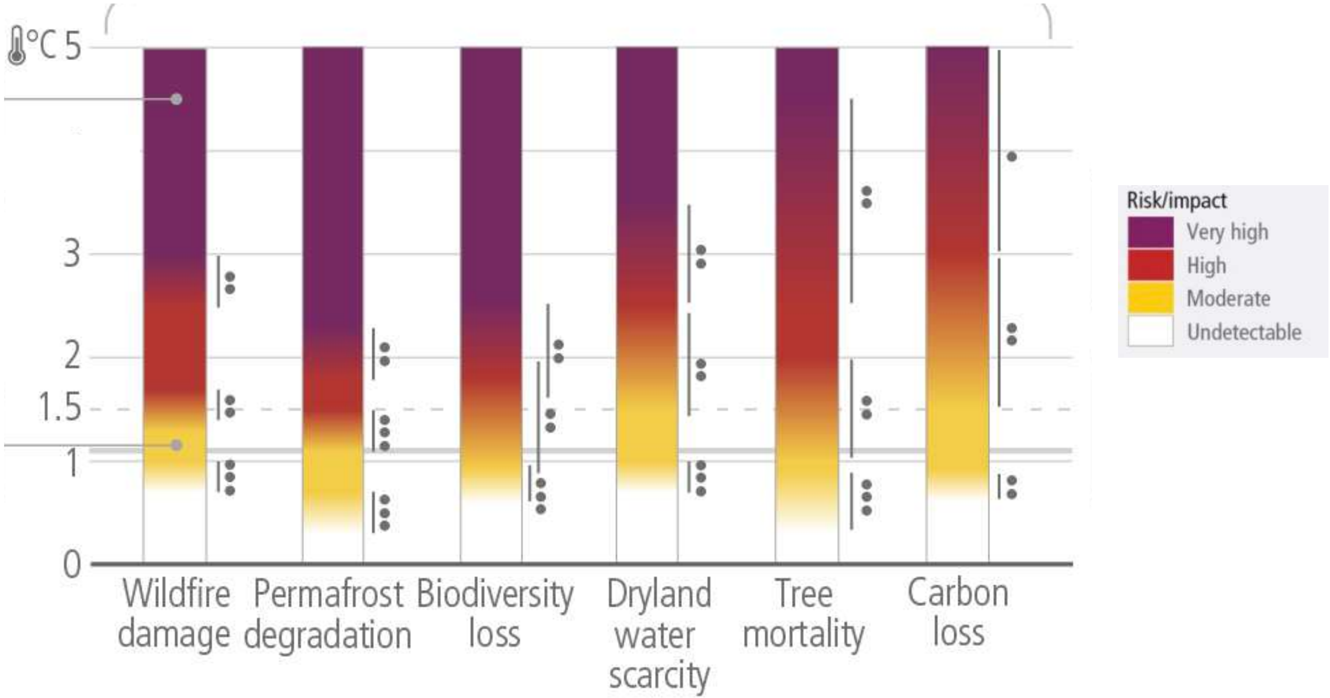
September Arctic sea-ice area (km^2)



Change in global surface temperature (°C)

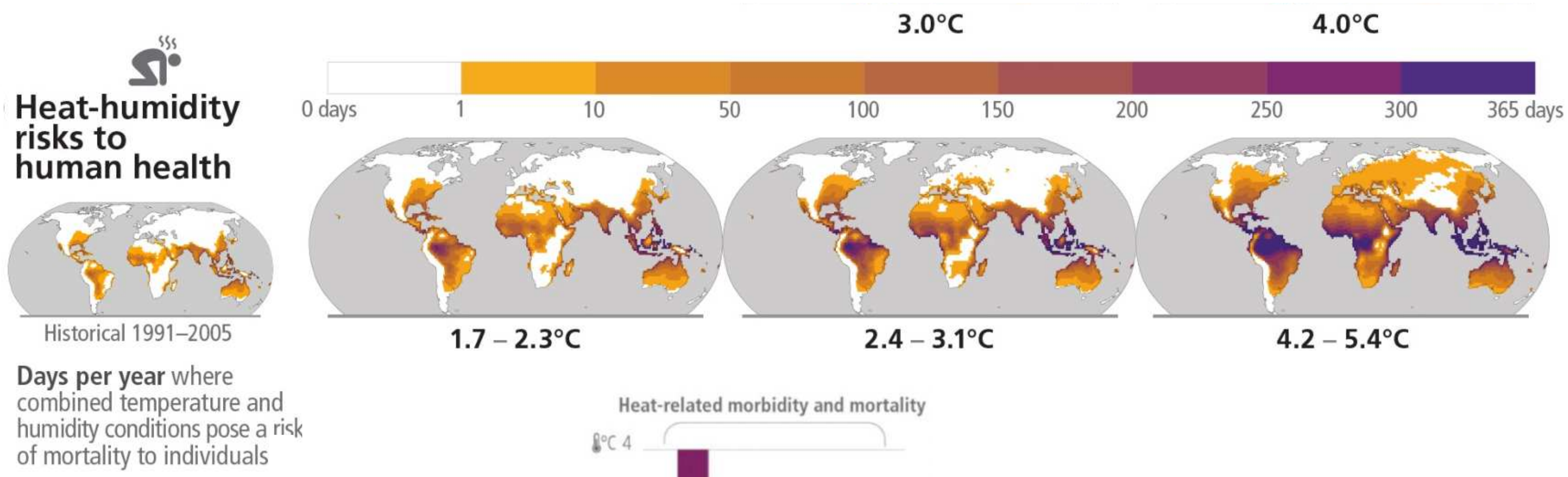
Delayed response of glaciers
- 15 kg ice per 1 kg of CO_2

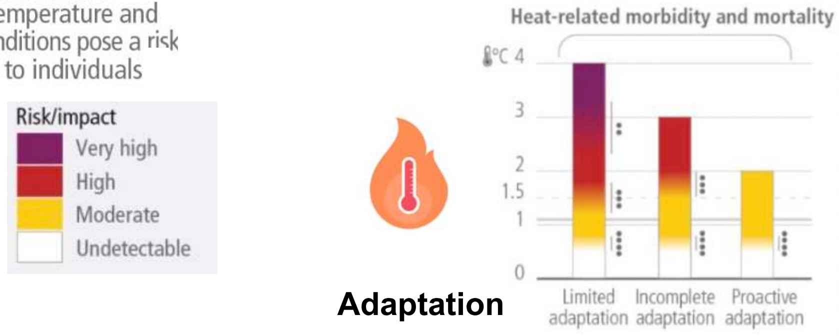
Key risks : land ecosystems



Hard limits for water, biomass and ecosystem-related responses

Key risks : human health

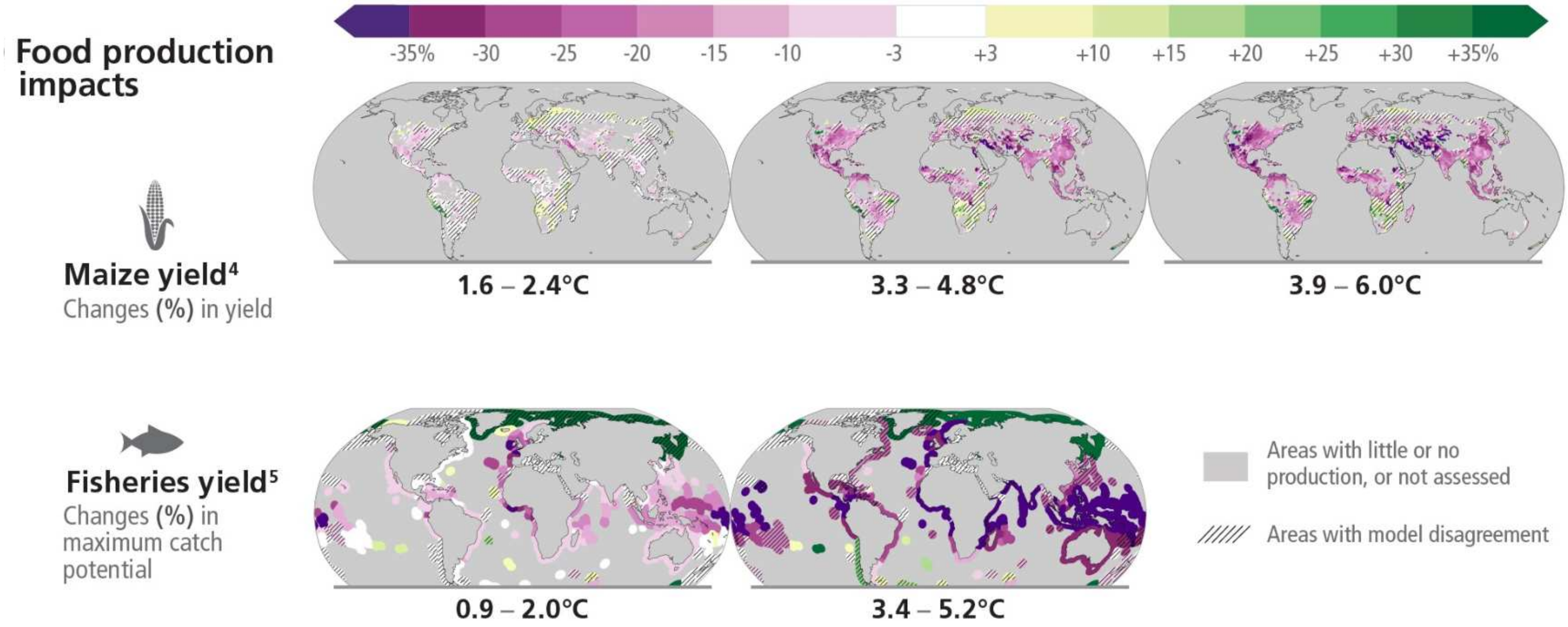




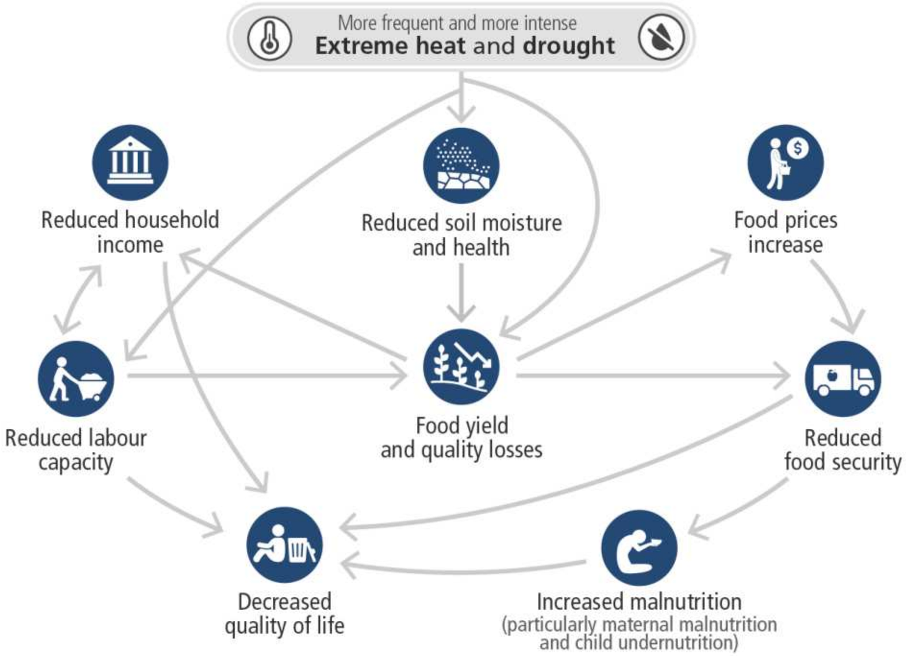
Adaptation

Climate action
= public health policy

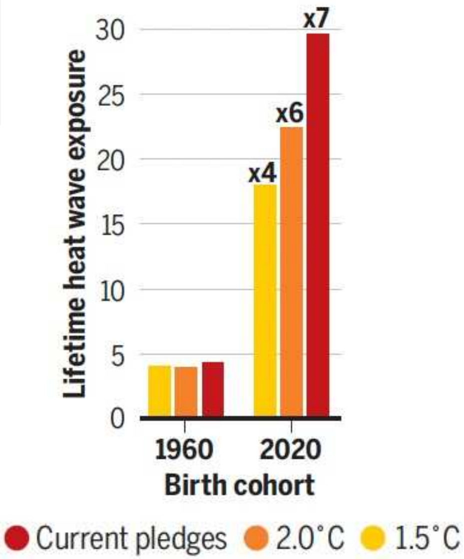
Key risks : food production



Increasingly complex risks

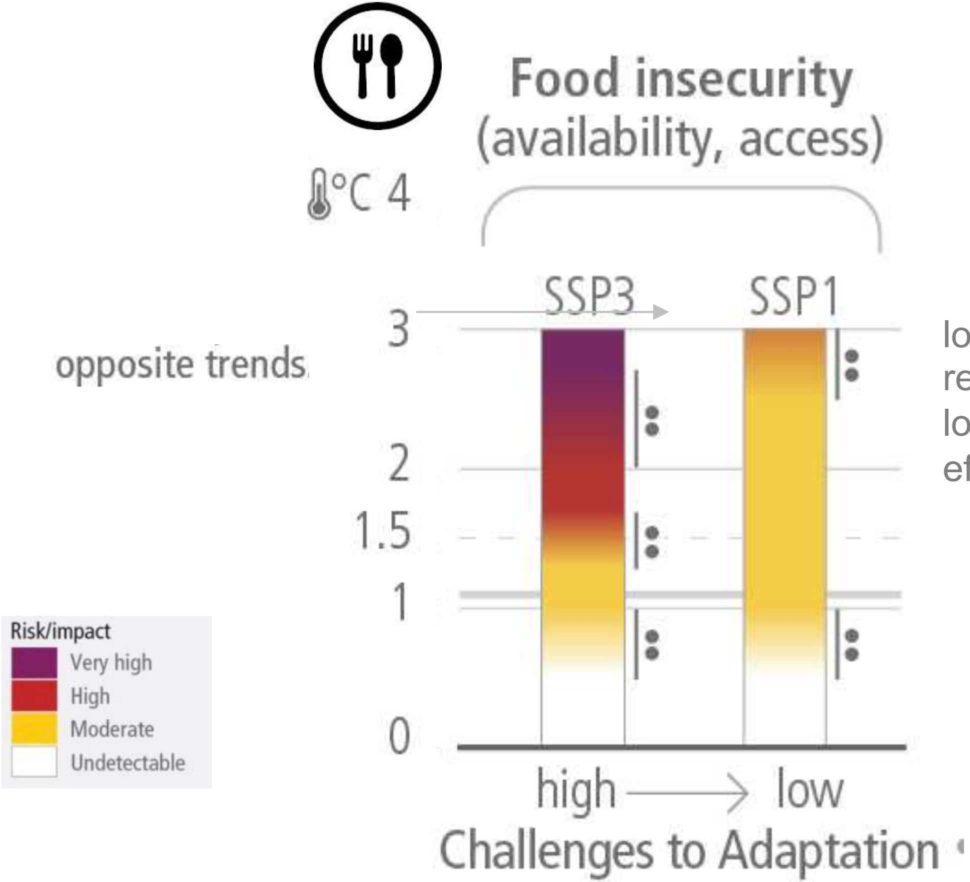


Lifetime exposure to hot extremes drastically increases for younger generations



Thiery et al, Science, 2021
https://myclimatefuture.info

Key risks : food insecurity



low population growth
reduced inequalities, high adaptive capacity
low GHG food production systems
effective land use regulation

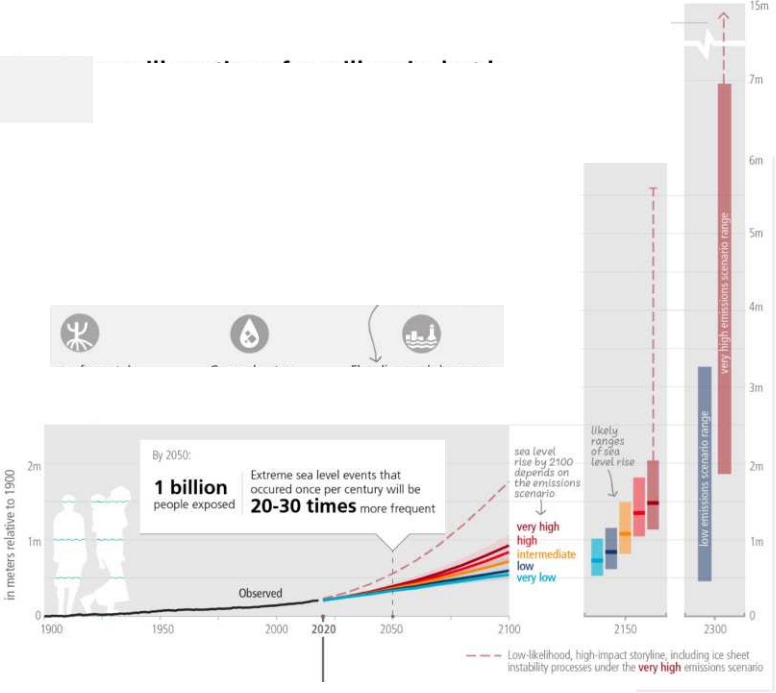
Food systems transformations

Key risks : sea level rise, irreversibility

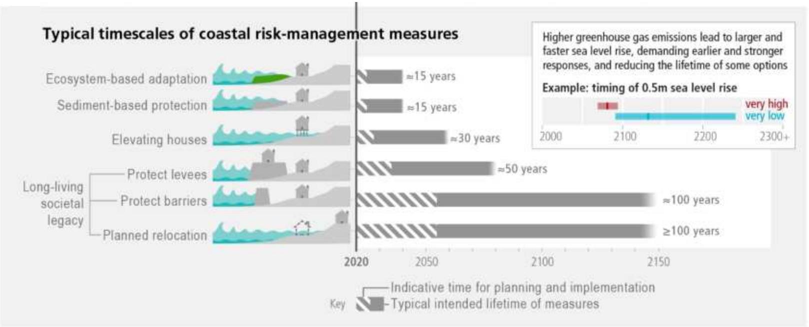
Committed future sea-level rise from past emissions

Future rate and magnitude depend on
future emissions
ice sheet processes (deep uncertainty)

The likelihood of future abrupt / irreversible changes increases with global warming



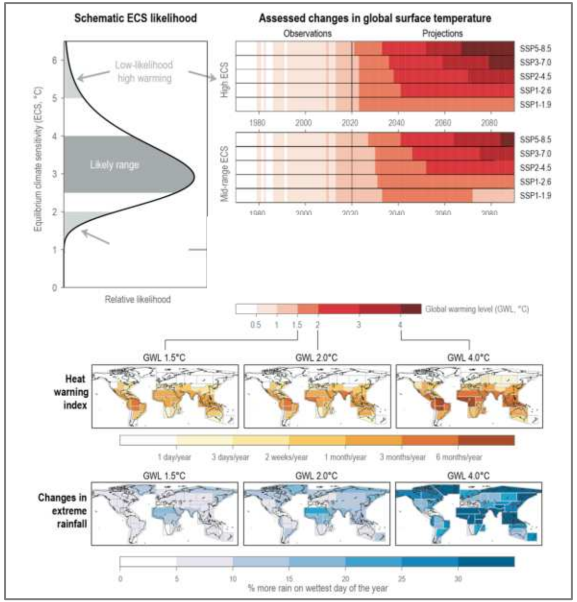
Responding to sea level rise requires long-term planning



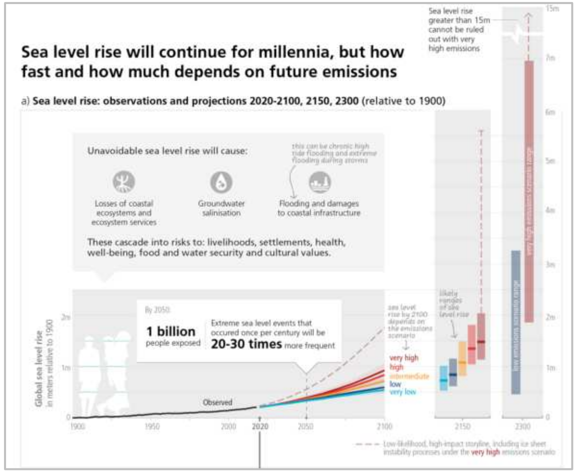
https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

Examples of low-likelihood, high-impact eventualities

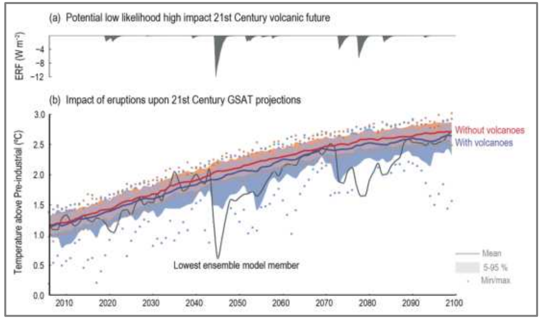
High-end climate response



Tipping points



Volcanic eruptions

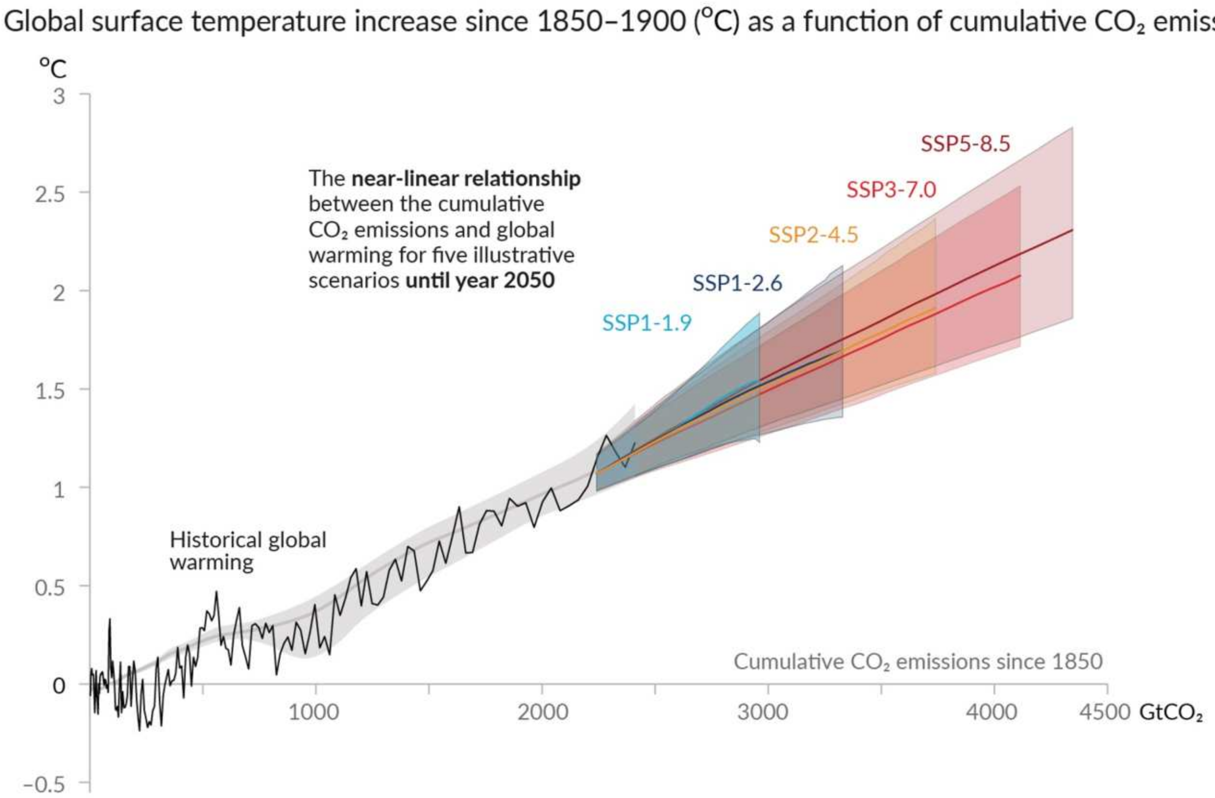


Compound, combined, cascading extremes

Full risk analysis

How to limit future global warming?

Every tonne of CO_2 emissions adds to global warming



Source: IPCC AR6 WG1 SPM.10

Remaining carbon budgets

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

Source: IPCC AR6 WG1 Table SPM.2

Updates to and clarifications of remaining carbon budgets show broad and increasing challenges

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of ~~2020~~ ($GtCO_2$) from the beginning of 2023 *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	~~900~~ 500	~~650~~ 300	~~500~~ 250	~~400~~ 150	~~300~~ 100	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	~~1450~~ 1100	~~1050~~ 800	~~850~~ 600	~~700~~ 500	~~550~~ 350	
2.0	0.93	~~2300~~ 2000	~~1700~~ 1450	~~1350~~ 1150	~~1150~~ 950	~~900~~ 800	

Central estimates require **deep reductions in other greenhouse gases** from 2020 to 2050.

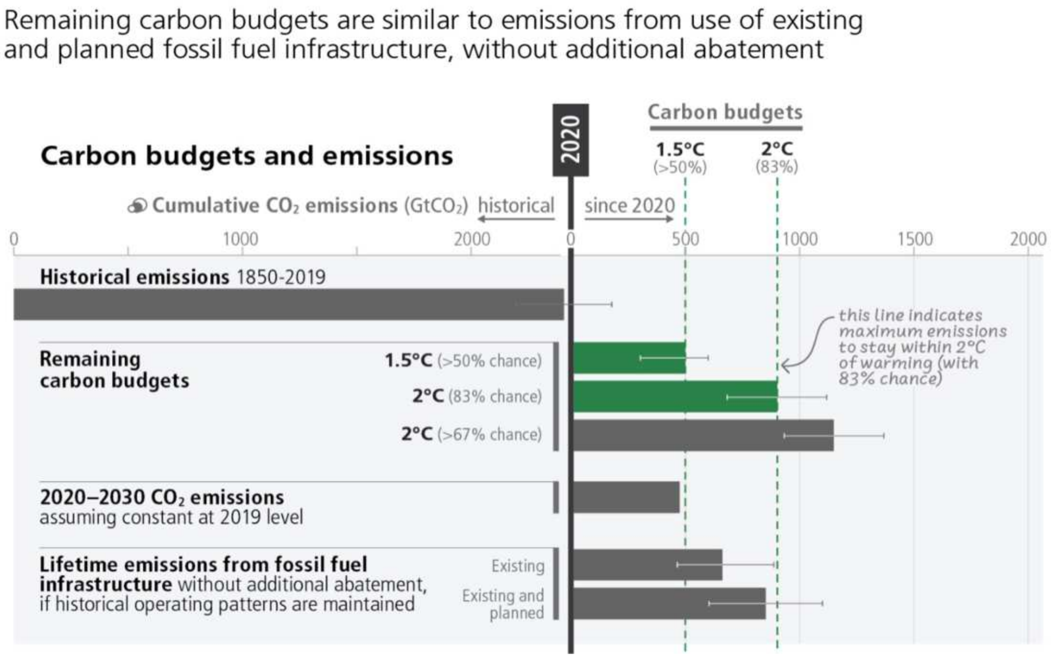
For **1.5°C carbon budgets**:
-50% for methane
-20% for nitrous oxide
-90% fluorinated gases

For **2°C carbon budgets**:
-35% for methane
-10% for nitrous oxide
-50% fluorinated gases

Updates since IPCC AR6 halve the remaining carbon budget for 1.5°C, and central estimates require equally stringent reductions in other greenhouse gases

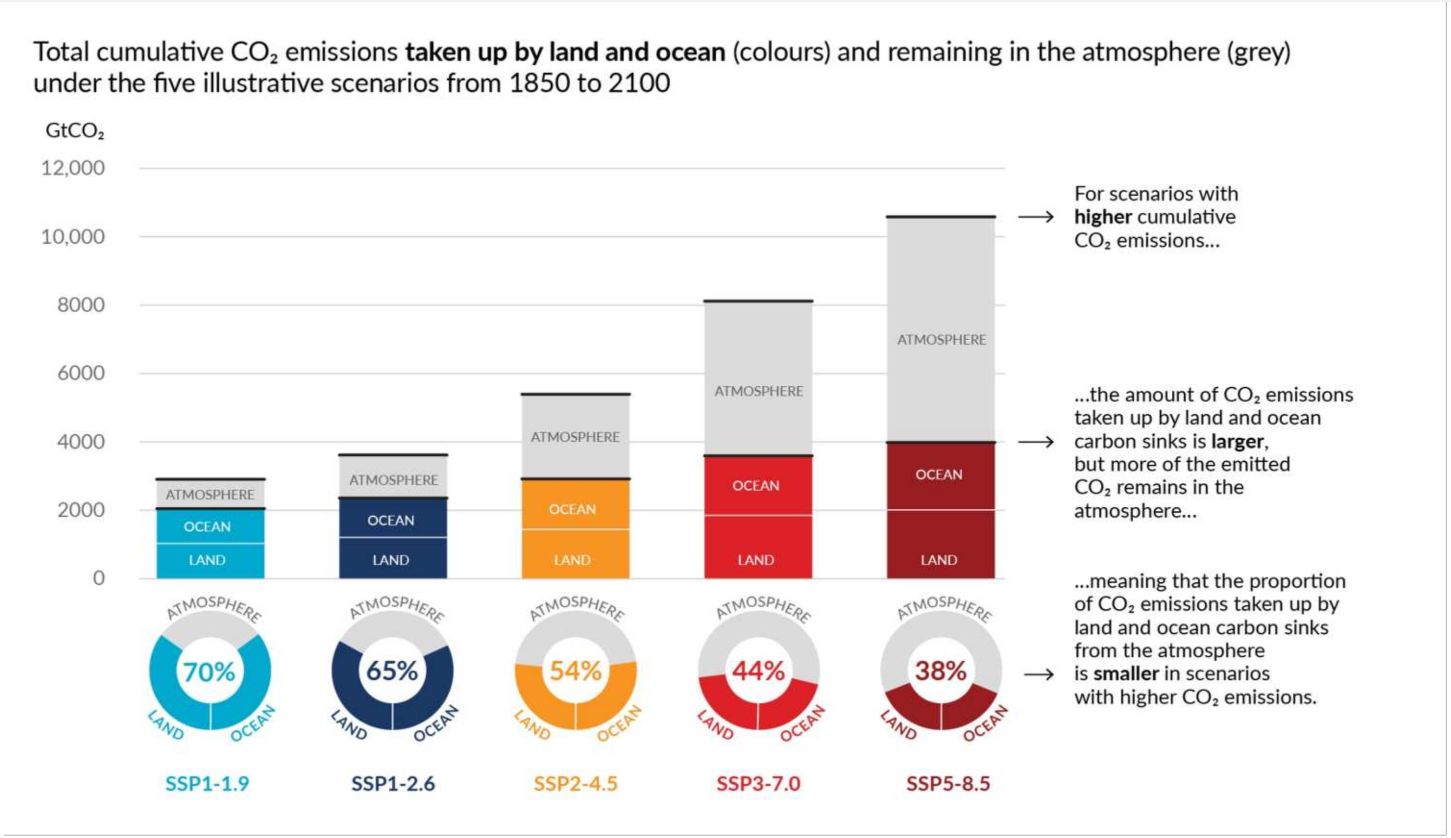
Source: IPCC AR6 WG1 Table SPM.2 ; Indicators of Global Climate Change (Forster et al, 2023); Rogelj & Lamboll (2024)

Remaining carbon budgets to limit warming to 1.5°C could soon be exhausted and those for 2°C largely depleted



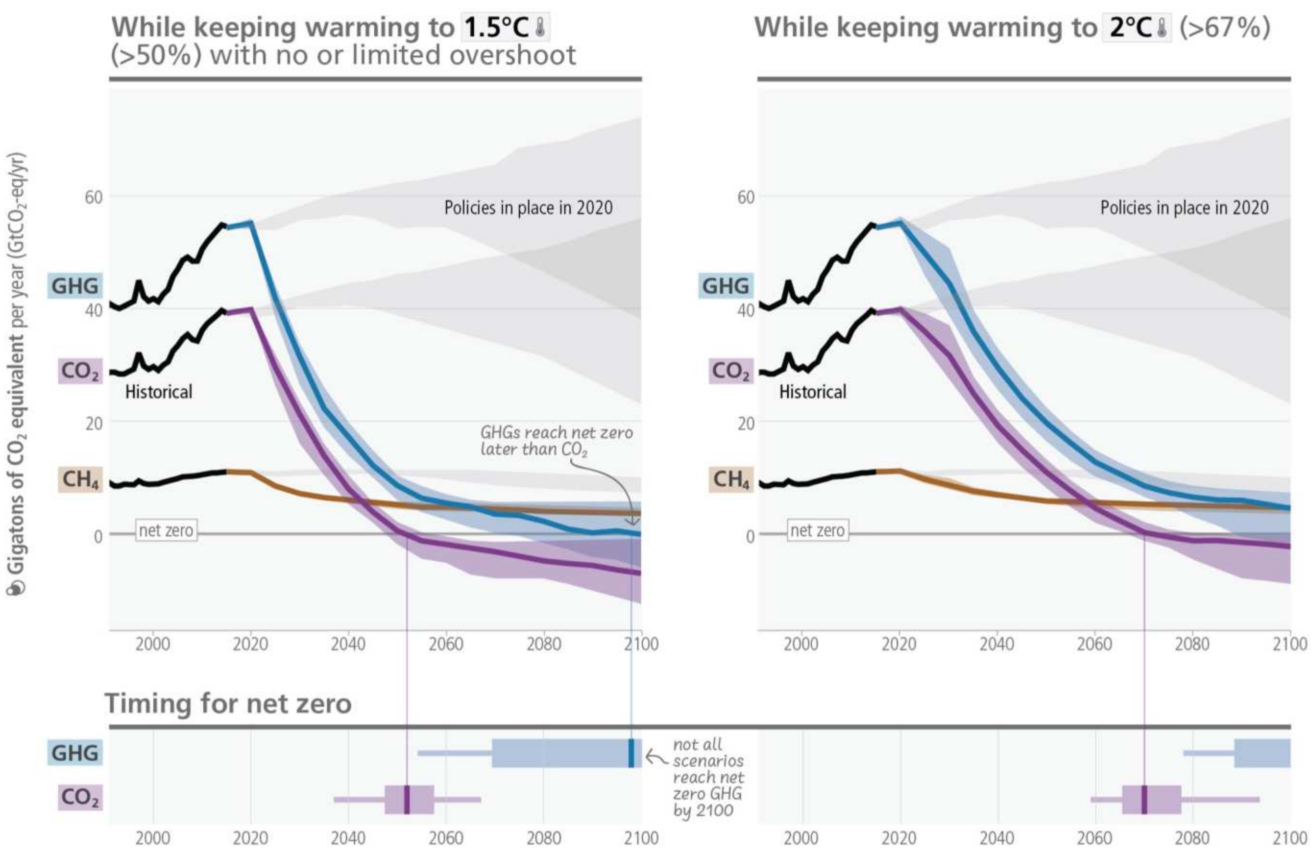
Source: IPCC AR6 SYR Figure 3.5

The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative emissions



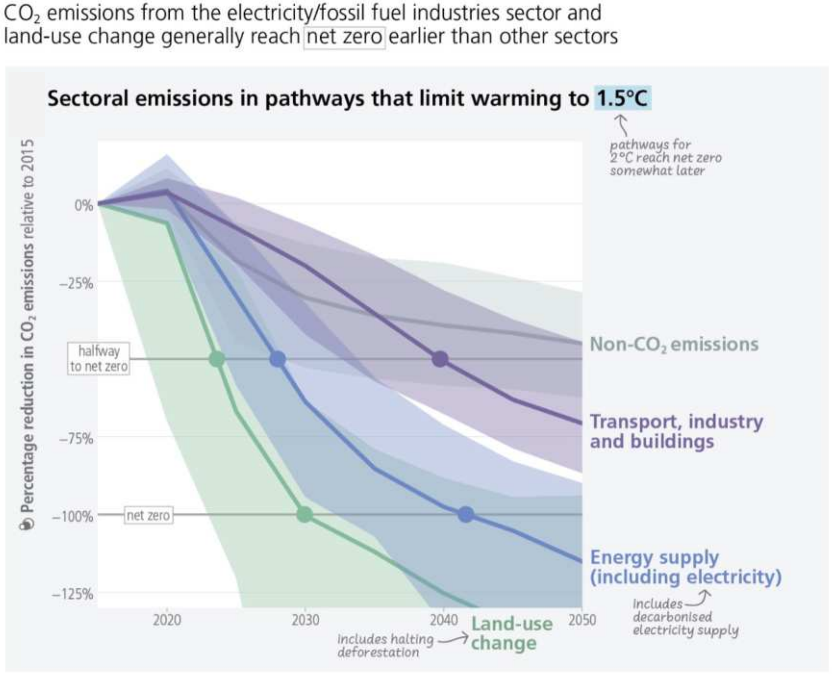
Source: IPCC AR6 WG1 SPM.7

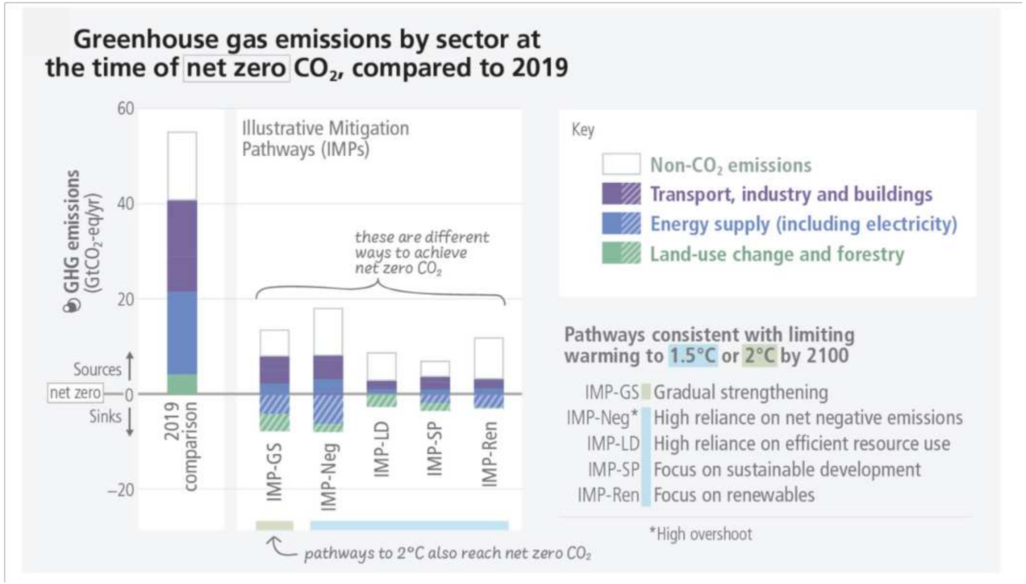
Global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot reach net zero CO_2 emissions around 2050



Source:
IPCC AR6
SYR Figure 3.6

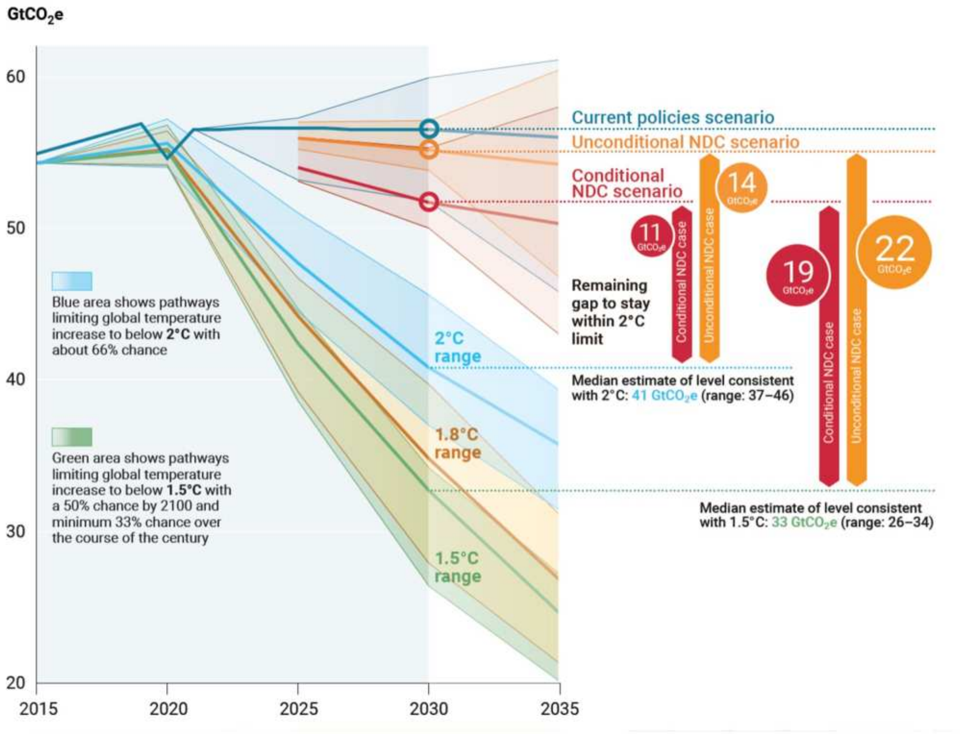
The transition towards net zero CO_2 will have different pace across different sectors



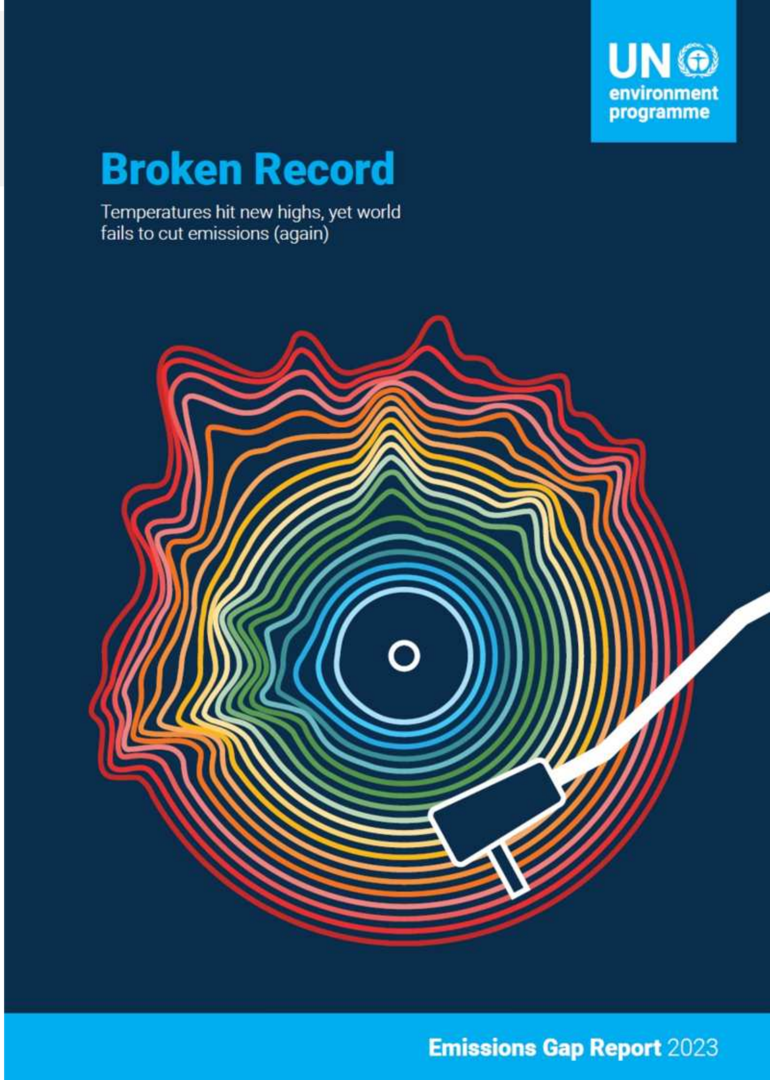


Source: IPCC AR6 SYR Figure 4.1

Current state of play?
An ambition and implementation gap



Source: Emissions Gap Report (2023) – Figure 4.2



United Nations
Framework Convention on
Climate Change

What are COP28 outcomes?

Responding to loss and damage

United Nations
Framework Convention on
Climate Change

Human-cause climate change impacts felt in every region
Those who have contributed the least being most vulnerable
Unequally distributed, fragmented, incremental adaptation responses
Adaptation gaps will continue to grow under current levels of implementation
Impacts & losses & damages will increase with every increment of warming

National inventories of impacts
Accessible, user-driven climate services systems, early warning for all

COP28 pledges
$ 0.77 B

Annual needs
$ 100 to 400 B
by 2030

Emergencies, sea-level rise, displacement, relocation, migration
Insufficient climate information and data,
Climate-resilient reconstruction and recover
How to avoid and respond to the risk of low-likelihood, high-impact outcomes

Source: UNFCCC COP28 Decision

Framework for global climate resilience

United Nations
Framework Convention on
Climate Change

National assessments

2030

Participatory and transparent adaptation plans and strategies
Mainstreaming implementation of adaptation

Water, food, health, ecosystems and biodiversity, nature-based solutions
Infastructures and settlements
Poverty, livelihoods, social protection measures, cultural heritage

Transformational adaptation

2027

Multi-hazard early warning systems
Improved climate-related data, information and services

Gender-responsive, human rights approaches

2030

Institutional capacity, operational systems for monitoring adaptation efforts, evaluation and learning
Science-based indicators, metrics and targets
Maladaptation avoidance

2024

Expert dialogue on the disproportionate impacts of climate change on **children** and relevant policy solutions

Source: UNFCCC COP28 Decision

Mitigation gaps acknowledged at COP28

United Nations
Framework Convention on
Climate Change

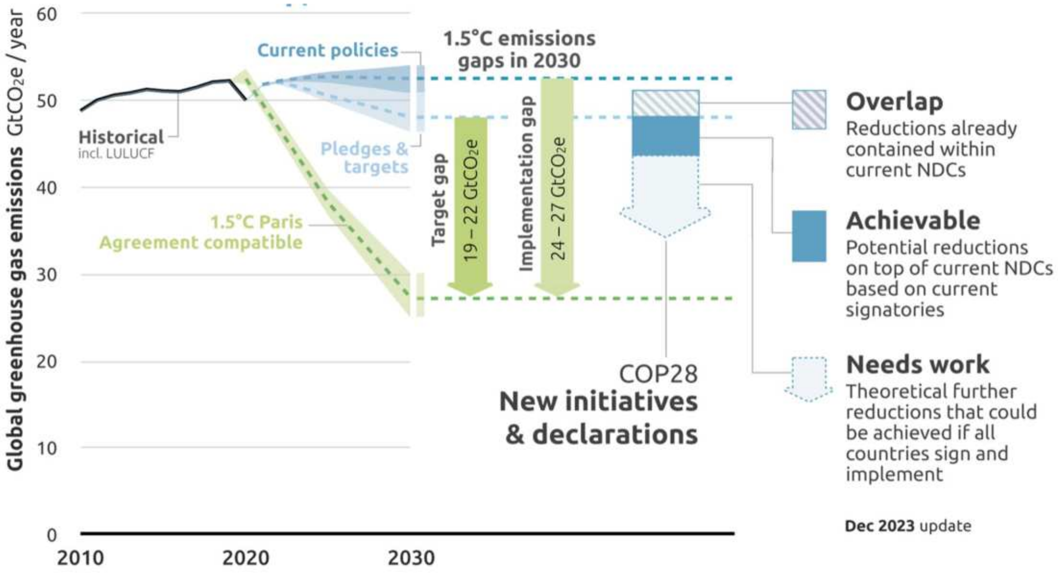
Implementation of nationally determined contributions would reduce emissions by 2% (up to 5.3% conditonnal on funding and support) from 2019 to 2030

Source: UNFCCC COP28 Decision

New COP28 initiatives and declarations

United Nations
Framework Convention on
Climate Change

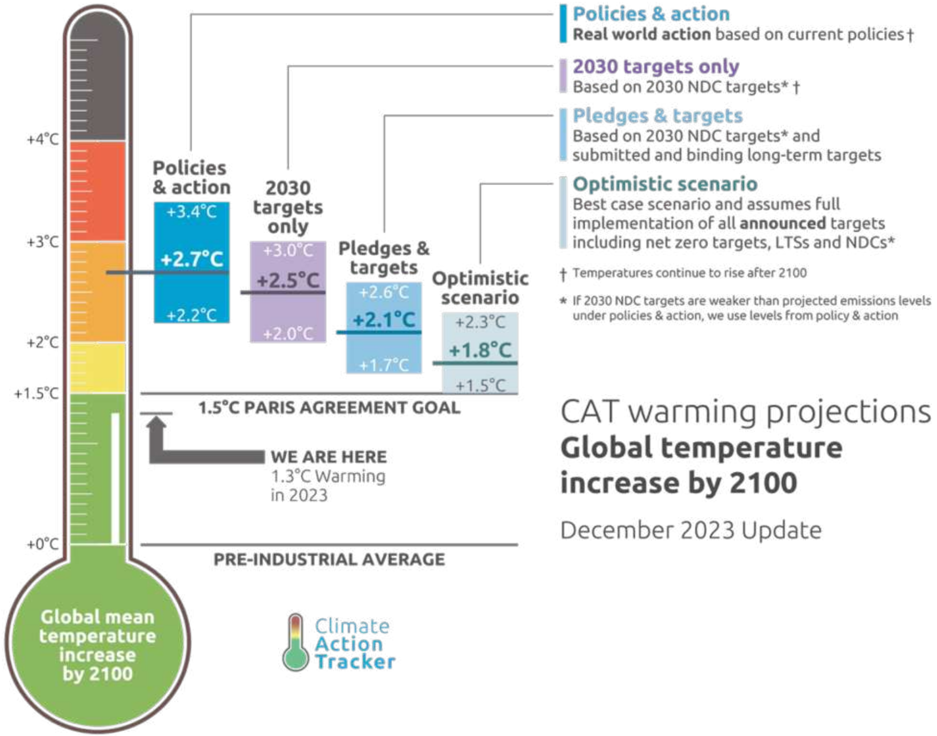
Renewables & energy efficiency, oil & gas decarbonisation, food & agriculture, cooling, carbon capture & storage



Source: UNFCCC COP28 Decision

New COP28 initiatives and declarations

United Nations
Framework Convention on
Climate Change



Source: Climate Action Tracker - December 2023 update

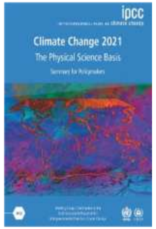
IPCC-related resources for teachers, to enhance climate literacy

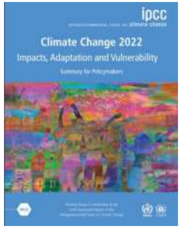
FAQs

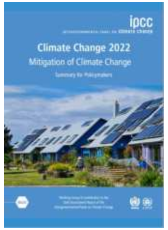
Fact sheets : regions, sectors

Interactive atlas
https://interactive-atlas.ipcc.ch

Sea-level projection atlas
https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool





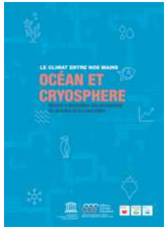


ClimateQ&A
https://climateqa.com

Summary for all

www.ipcc.ch

Office for Climate Education



https://www.oce.global/en/ressources