

Limiting global warming to 1.5°C: Our physical insights on the climate emergency

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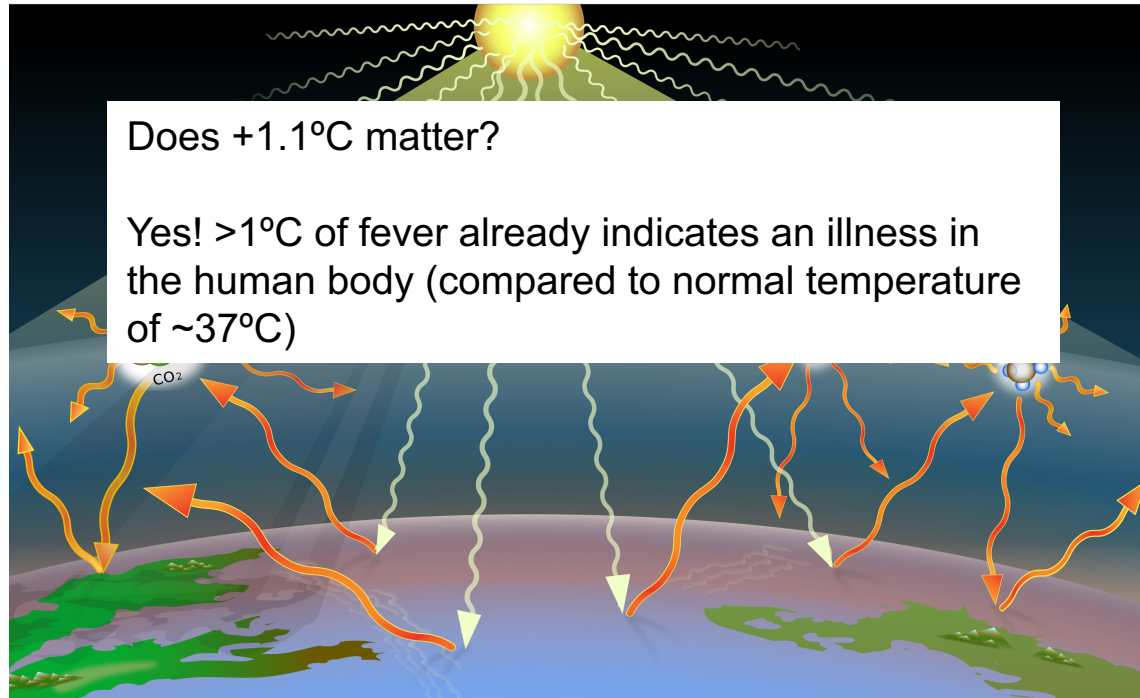
#ClimateReport #IPCC



“Blue marble”, Apollo 17, 1972

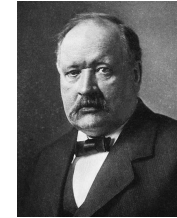


"Sunset over Earth", NASA, 11/2009



- Without greenhouse effect => Mean global temperature would be 33°C lower
- Greenhouse effect due to human activity => Additional warming since pre-industrial time = +1.1°C during last decade (IPCC AR6)

Greenhouse gas effect due to CO₂ concentrations is already estimated since more than 100 years (Arrhenius, 1896; based on Fourier, Tyndall)



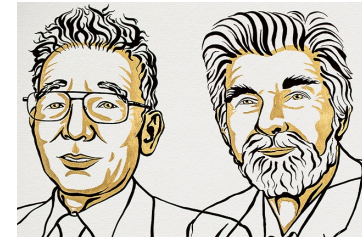
Svante Arrhenius
(Nobel prize in
Chemistry, 1903)

Greenhouse gas effect due to CO₂ concentrations is already estimated since more than 100 years (Arrhenius, 1896; based on Fourier, Tyndall)



Svante Arrhenius
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Chemistry, 1903)

Science underlying climate models and attribution of climate signals to human influence is established since more than 40 years



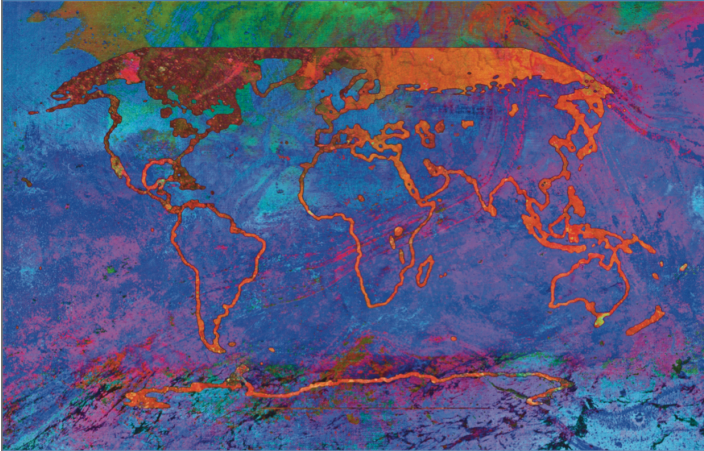
Syukoro Manabe & Klaus Hasselmann
($\frac{1}{4}$ & $\frac{1}{4}$ of 2021 Physics Nobel prize)

ipcc
INTERGOVERNMENTAL PANEL ON climate change

Climate Change 2021

The Physical Science Basis

Summary for Policymakers



WG1

Working Group I contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

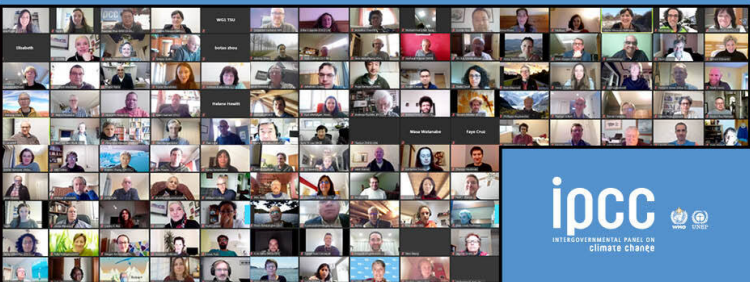

WMO UNEP

WORKING GROUP I CONTRIBUTION TO THE IPCC SIXTH ASSESSMENT REPORT
FIRST LEAD AUTHOR MEETING
GUANGZHOU, CHINA, 25-29 JUNE 2018

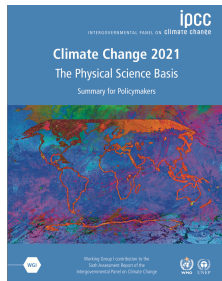


IPCC AR6 Working Group I Third Lead Author Meeting
Toulouse, France, 26-30 August 2019





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INTERGOVERNMENTAL PANEL ON climate change



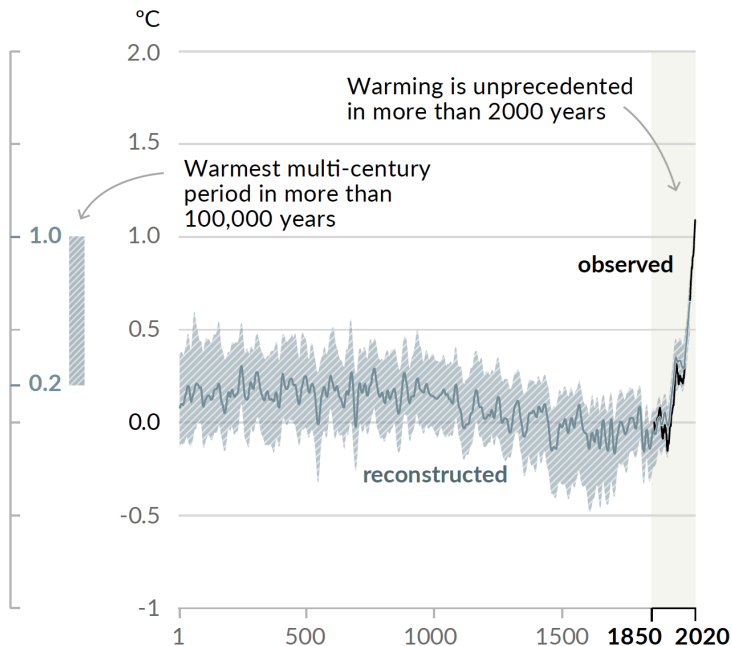
Chapter 11 team:

Sonia I. Seneviratne, Xuebin Zhang

Muhammad Adnan, Wafae Badi, Claudine Dereczynski, Alejandro Di Luca, Subimal Ghosh, Iskhaq Iskandar, James Kossin, Sophie Lewis, Friederike Otto, Izidine Pinto, Masaki Satoh, Sergio M. Vicente-Serrano, Michael Wehner, Botao Zhou

Changes in global surface temperature relative to 1850-1900

Change in global surface temperature (decadal average)
as **reconstructed** (1-2000) and **observed** (1850-2020)

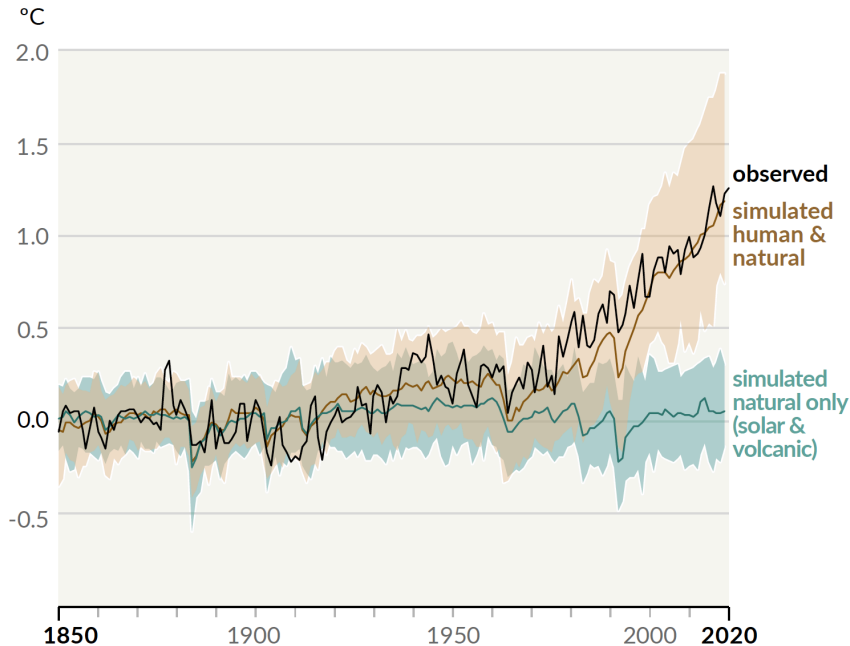


(IPCC AR6, Fig. SPM.1)

- We already had **1.1°C (1.09°C)** of global warming in 2011-2020 compared to 1850-1900
- The warming rate is **unprecedented** in more than 2000 years, the temperature level is unprecedented in more than 100'000 years
- The largest part of this warming is **irreversible** for several generations

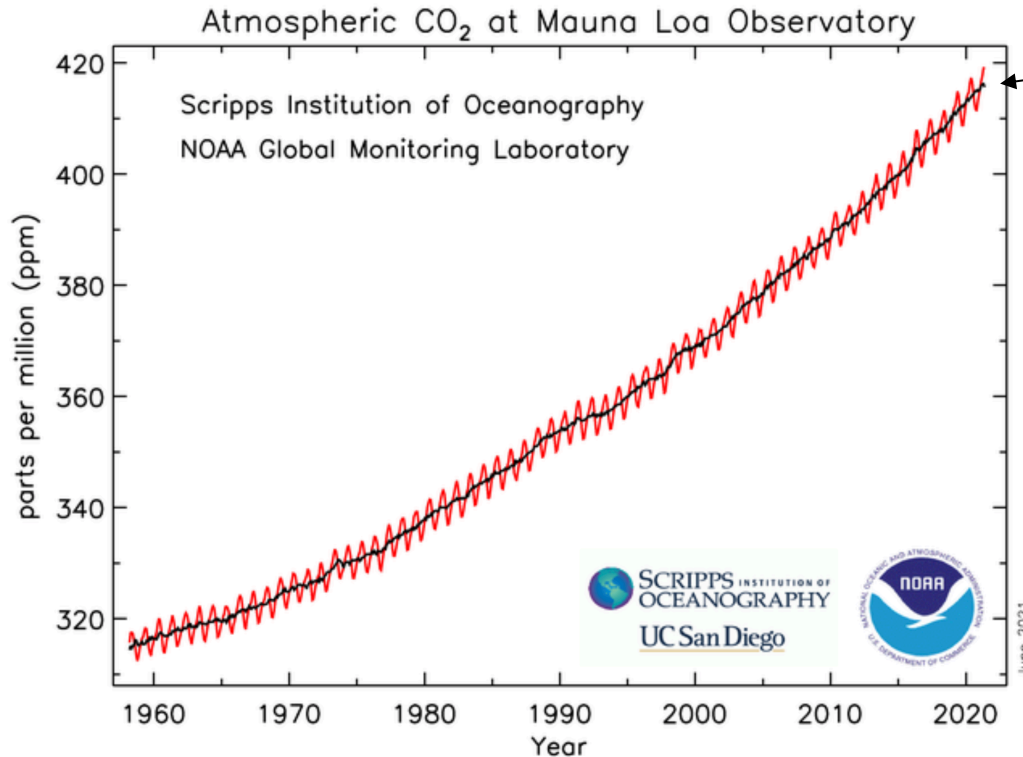
Changes in global surface temperature relative to 1850-1900

Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020)



- IPCC AR6: “It is **unequivocal** that human influence has warmed the atmosphere, ocean and land”
- Best estimate: **About all of the global warming** is due to human-induced emissions

(IPCC AR6, Fig. SPM.1)

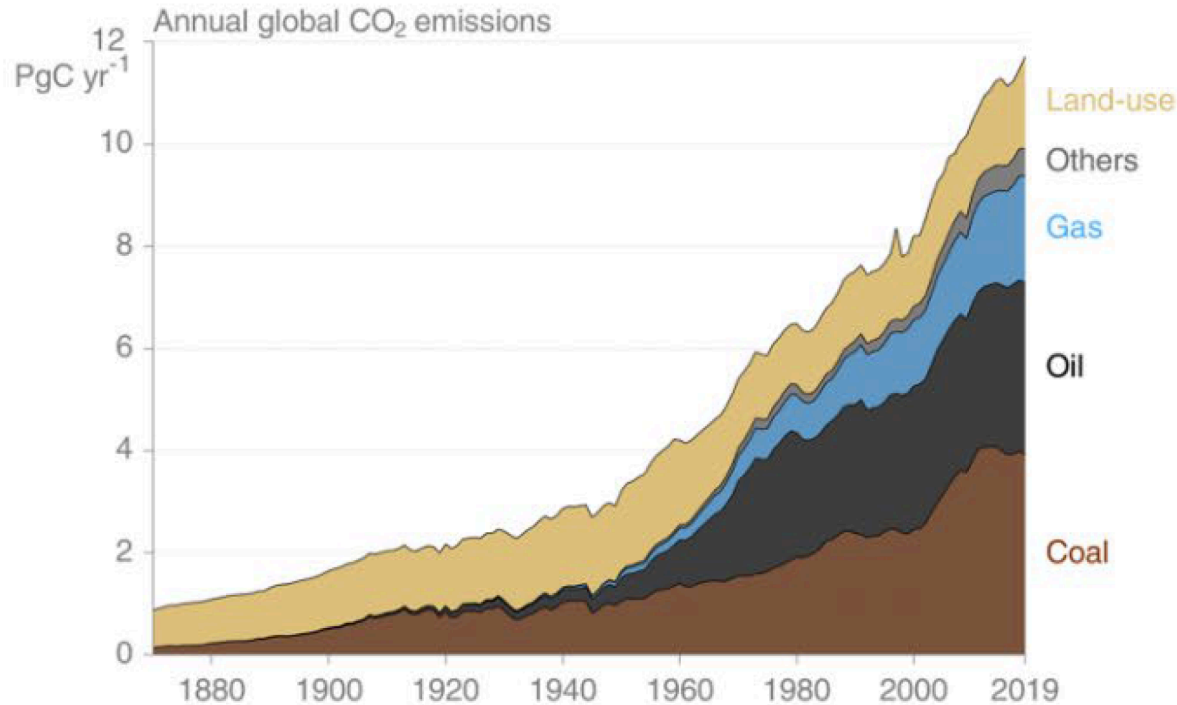


May 2021: New record,
419.13 ppm

First IPCC report: 1990
Kyoto protocol: 2005
IPCC Nobel Peace Prize: 2007
Paris agreement: 2015
IPCC special report on 1.5C: 2018
Greta Thunberg: 2018-2021
COVID Crisis: 2020-2021

CO₂ concentrations are increasing unabatedly no matter how much scientific information is produced, fought, shared, discussed...

The cause of human-induced global warming is clear



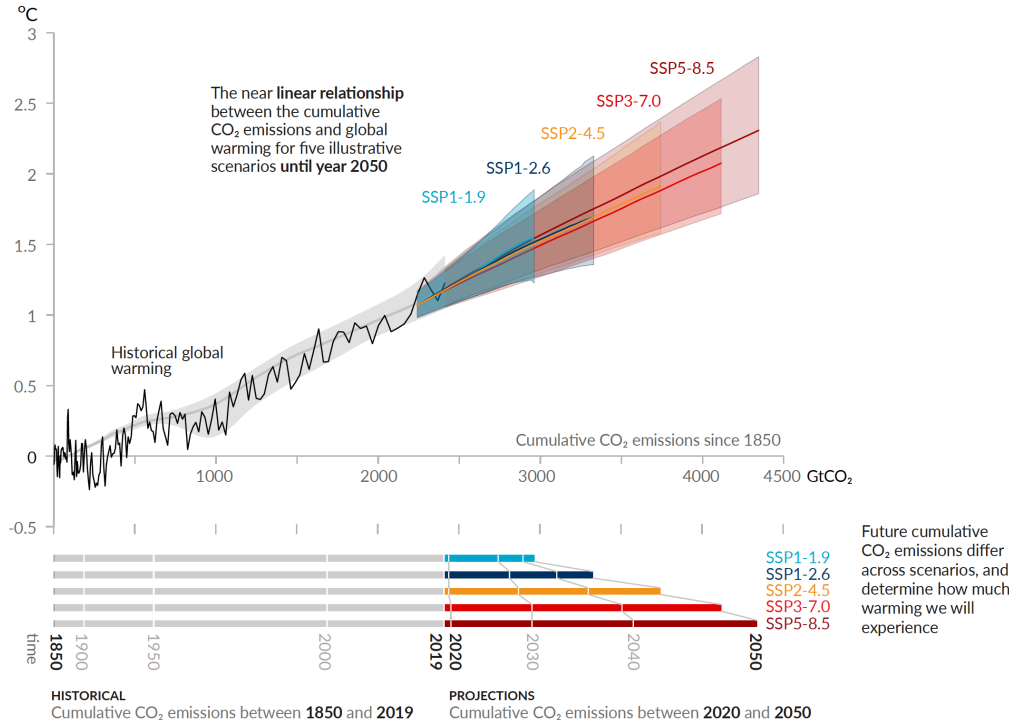
Sources of CO₂ emissions:

- Burning of fossil fuels
- Land use (deforestation)

(IPCC AR6, Chapter 5: Figs. 5.6 and 5.5)

Every tonne of CO₂ emissions adds to global warming

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO₂ emissions (GtCO₂)



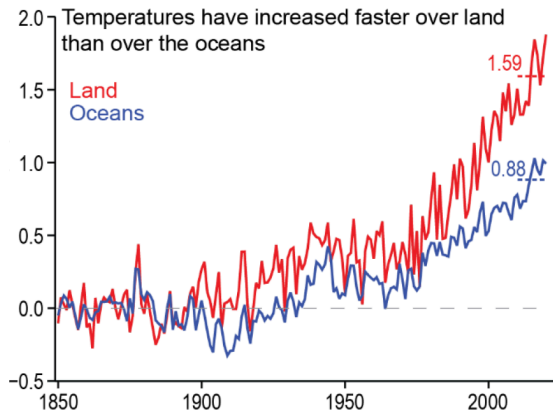
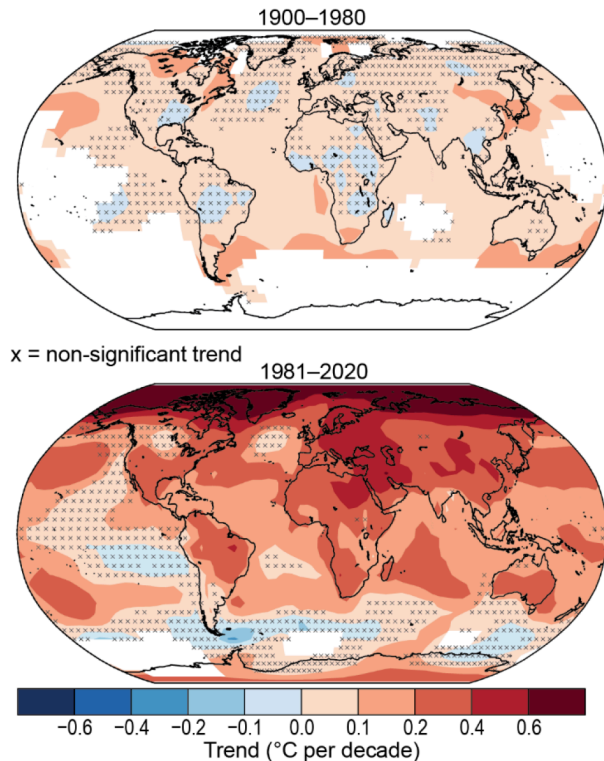
Direct relationship
between cumulative CO₂
emissions and global
warming

Every additional emissions
of CO₂ lead to additional
global warming

Very small remaining CO₂
budget for a stabilisation
at ca. 1.5°C (1.6°C)

(IPCC AR6, Fig. SPM.10)

Warming accelerated after the 1970s, but not all regions are warming equally



Temperature observations reveal **warming acceleration** after the 1970s

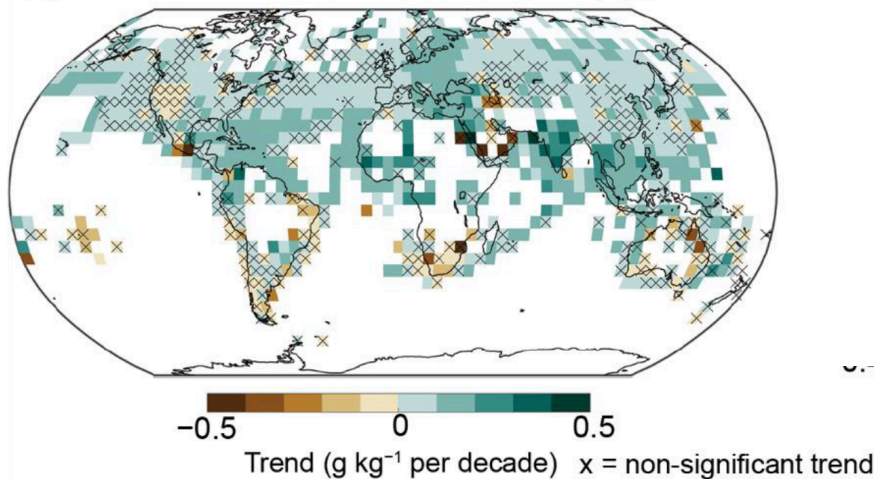
Land regions are warming substantially more than the global mean: **1.6°C (1.59°C)**

(IPCC AR6, Chapter 2, Fig. 2.11)

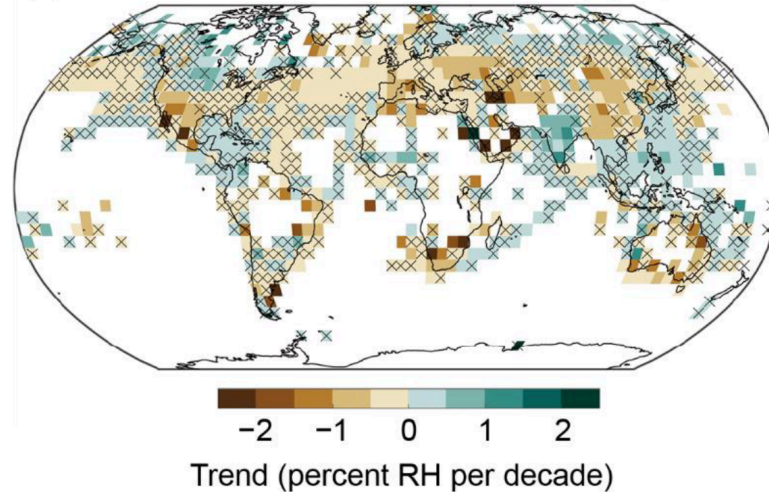
Combined tendency to wetting and drying: More moisture in the air, but further from saturation point

«When it rains, it pours», but also more potential for drying soils

(a) Trends in surface specific humidity (q)



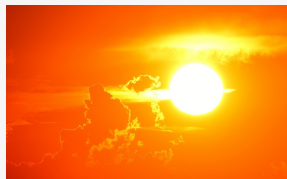
(c) Trends in surface relative humidity (RH)



(IPCC AR6, Ch8)

- Evidence of observed changes in extremes has **strengthened** in particular for **extremes related to water cycle**: precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather)

(IPCC AR6)



Temperature extremes



Heavy precipitation



Floods



Droughts



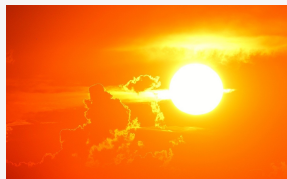
Storms



Compound events

- Evidence of observed changes in extremes has **strengthened** in particular for **extremes related to water cycle**: precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather)
- Human-induced climate change is already affecting many weather and climate extremes in **every region** across the globe

(IPCC AR6)



Temperature extremes



Heavy precipitation



Floods



Droughts

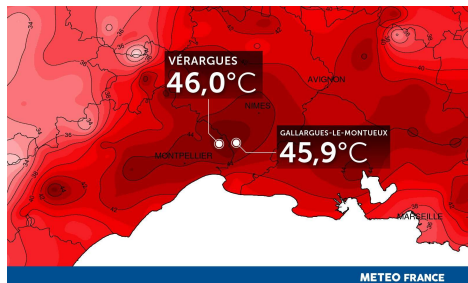


Storms



Compound events

2019-2021: Events made more likely because of human-induced climate change



France, 2019



Australia, 2019-2020



Siberia, 2020



Canada, 2021



Western Europe, 2021



Mediterranean, 2021

Switzerland: Heat waves (2018, 2019); Extreme rainfall (2018, 2021); Crop impacts due to late frost (2021)

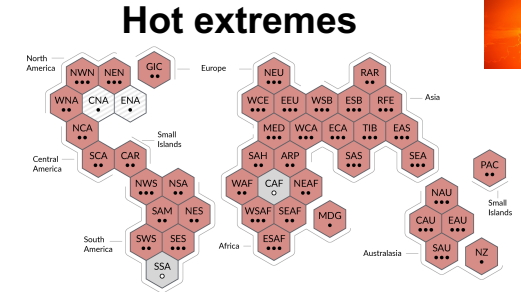
Climate change is already affecting **every inhabited region across the globe**, with human influence contributing to many observed changes in weather and climate extremes

-  Low agreement in the type of change
-  Limited data and/or literature

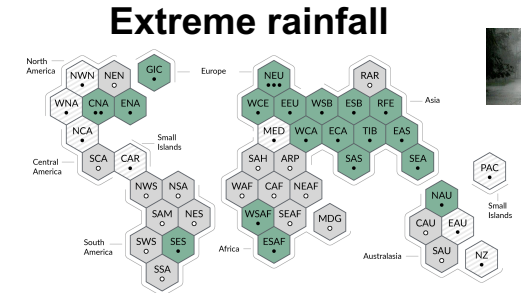
Confidence in human contribution to the observed change

- High
- Medium
- Low due to limited agreement
- Low due to limited evidence

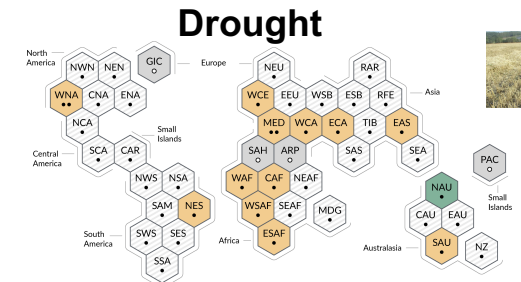
-  Increase (41)
-  Decrease (0)



-  Increase (19)
-  Decrease (0)



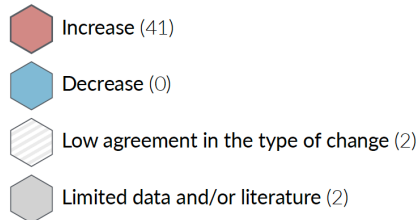
-  Increase (12)
-  Decrease (1)



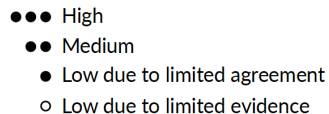
“It is *virtually certain* that **hot extremes** have become more frequent and more intense across **most land regions**”

“There is *high confidence* that **human-induced climate change** is the **main driver** of these changes”

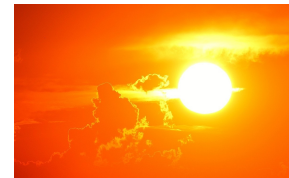
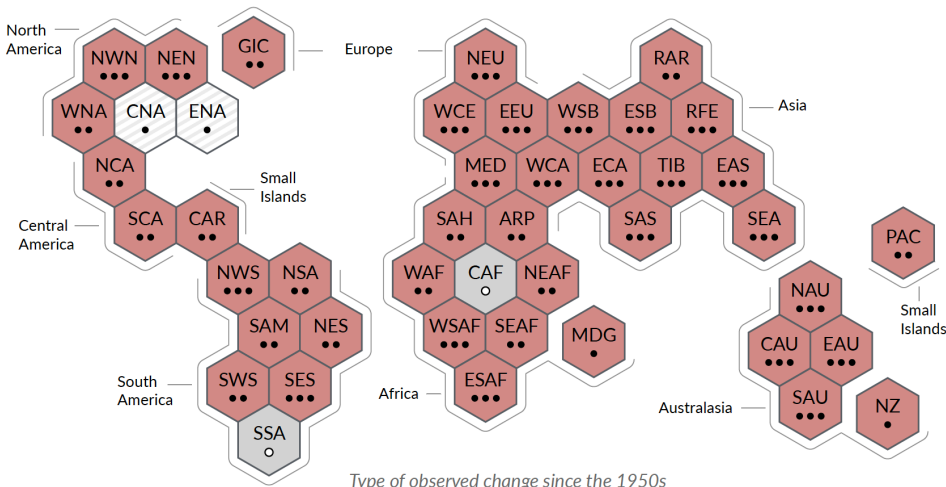
Type of observed change in hot extremes



Confidence in human contribution to the observed change



a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



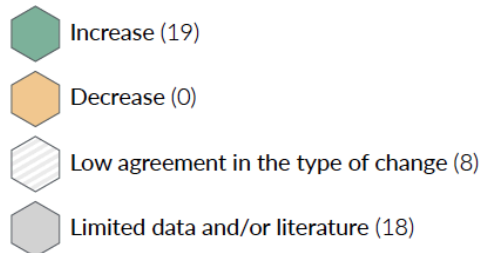
(IPCC AR6, Fig. SPM.3)

Heavy precipitation events are increasing in almost all regions with observations

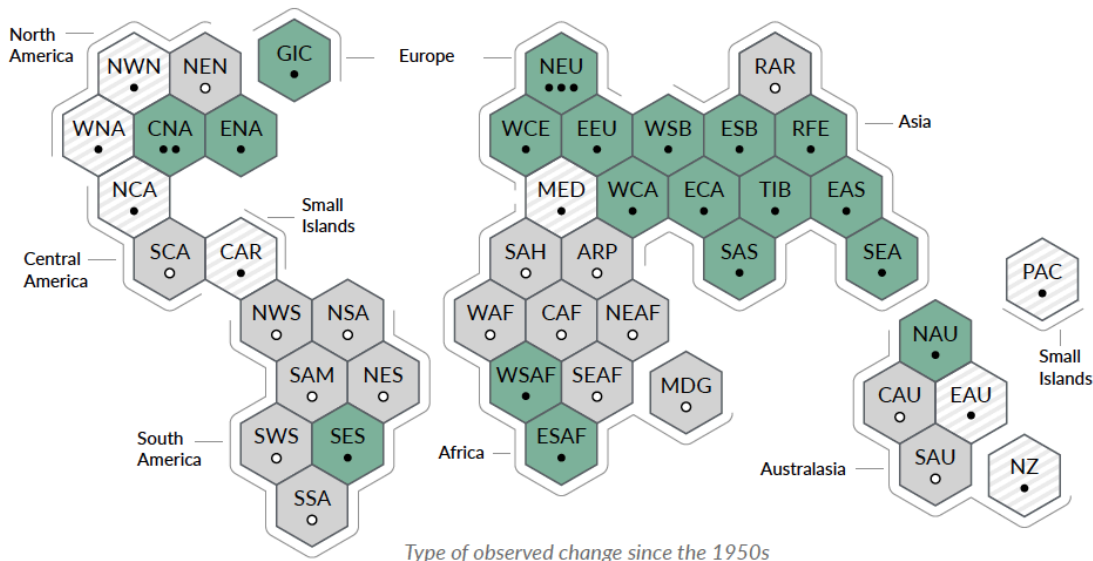
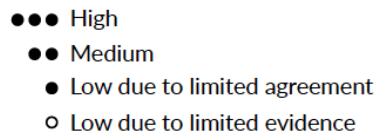


b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions

Type of observed change in heavy precipitation



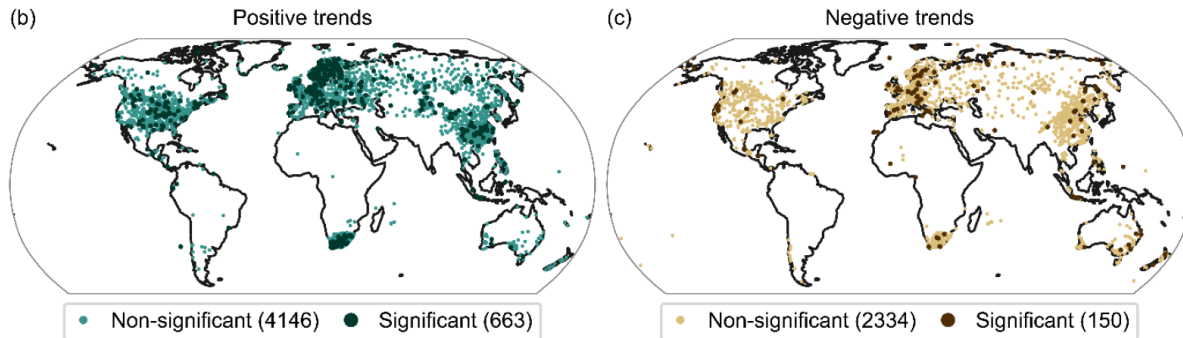
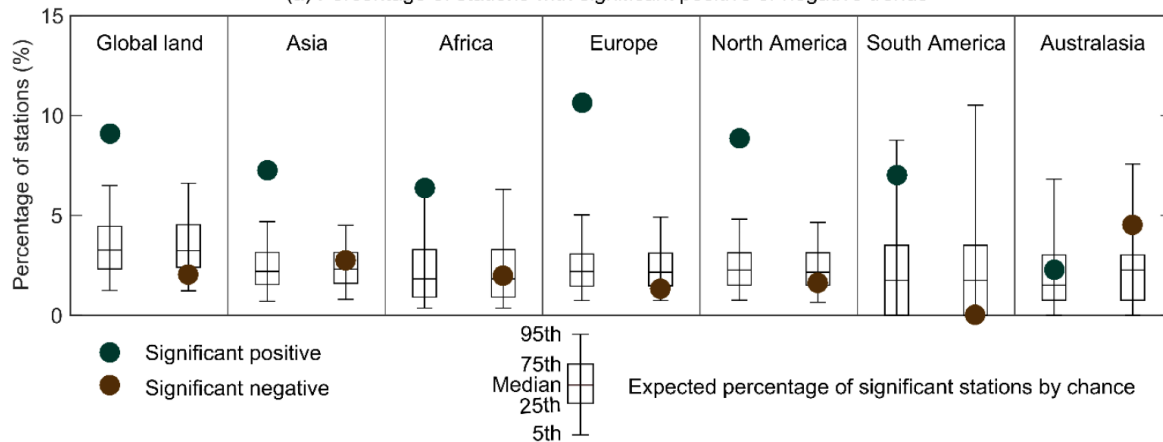
Confidence in human contribution to the observed change



(IPCC AR6, Fig. SPM.3)

Observed trends in annual maximum daily precipitation (Rx1day)

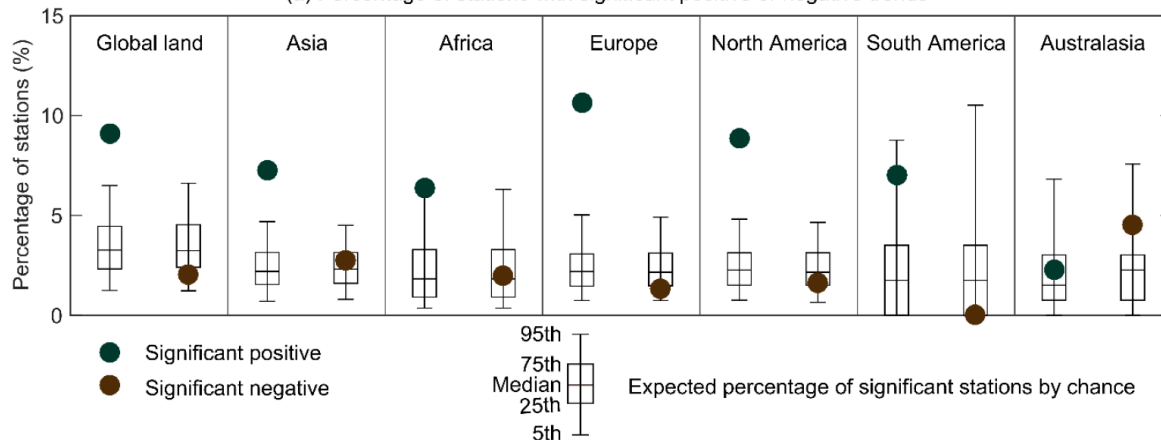
(a) Percentage of stations with significant positive or negative trends



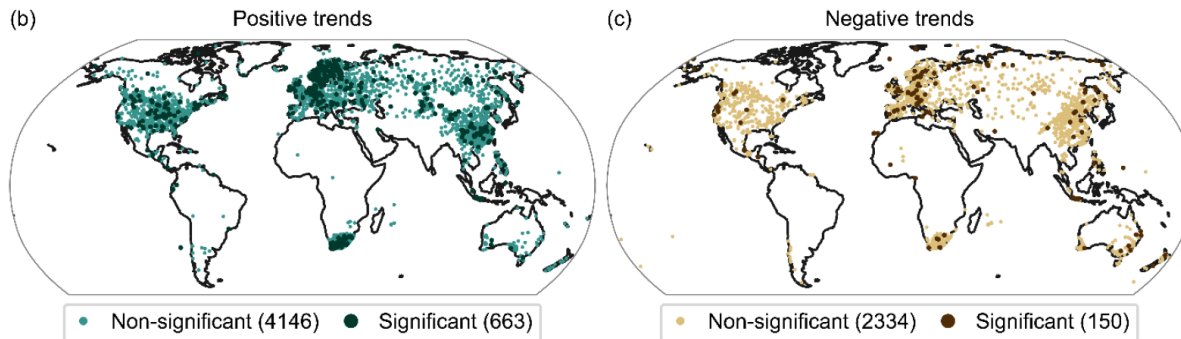
(IPCC AR6, Ch11)

Observed trends in annual maximum daily precipitation (Rx1day)

(a) Percentage of stations with significant positive or negative trends



The frequency and intensity of heavy precipitation events have *likely* increased at the global scale over a majority of land regions with good observational coverage.



Heavy precipitation has *likely* increased on the continental scale over three continents: North America, Europe, and Asia.

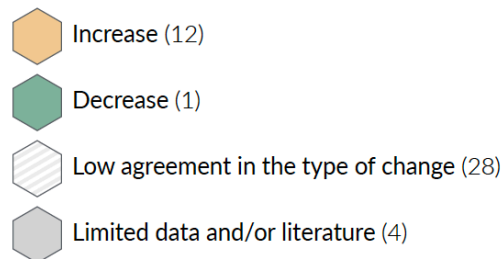
(IPCC AR6, Ch11)

Droughts are increasing in some regions due to increased evapotranspiration

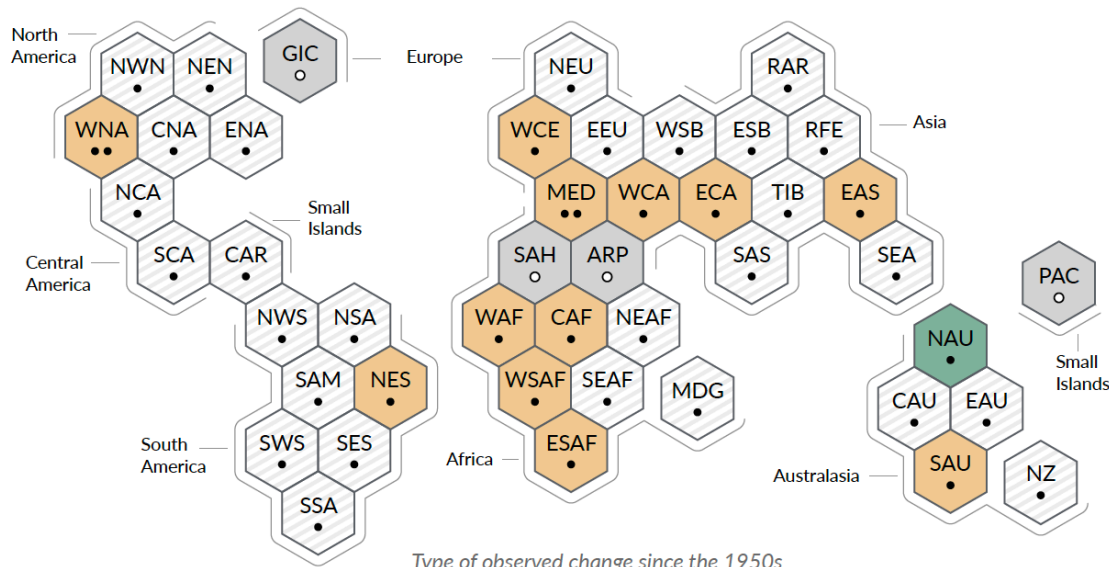
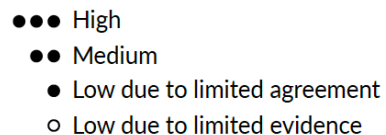


c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in agricultural and ecological drought



Confidence in human contribution
to the observed change



Type of observed change since the 1950s

(IPCC AR6, Fig. SPM.3)

- Event attribution studies and physical understanding indicate **that human-induced climate change increases heavy precipitation associated with tropical cyclones** (*high confidence*)
- It is *likely* that the global proportion of **major** (Category 3–5) **tropical cyclone** occurrence has increased over the last four decades.



(IPCC AR6)

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- It is *likely* that the global proportion of **major** (Category 3–5) **tropical cyclone** occurrence has increased over the last four decades.



Human influence has *likely* increased the chance of **compound extreme events** since the 1950s:

- **concurrent heatwaves and droughts** on global scale (*high confidence*)
- **fire weather** in some regions of all inhabited continents (*medium confidence*)
- **compound flooding** in some locations (*medium confidence*)



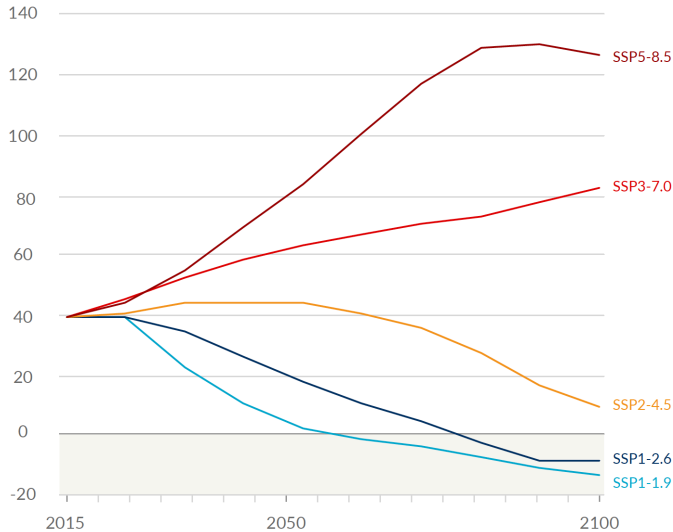
It depends on our decisions and emissions!

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	Very likely range (°C)	Best estimate (°C)	Very likely range (°C)	Best estimate (°C)	Very likely range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

(IPCC AR6)

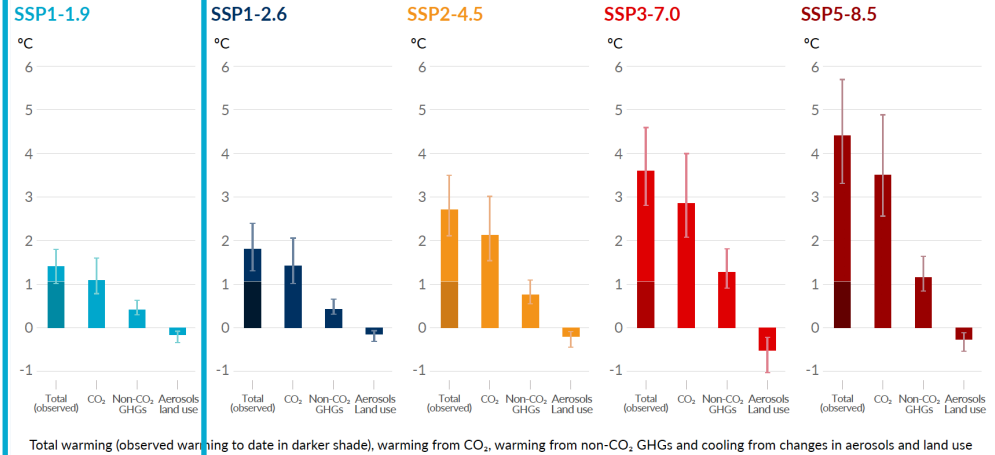
Projections

Carbon dioxide (GtCO₂/yr)



Contribution to global surface temperature increase from different emissions, with a dominant role of CO₂ emissions

Change in global surface temperature in 2081-2100 relative to 1850-1900 (°C)



Only 1 scenario compatible with aim of Paris agreement (“well below 2°C” and “pursuing efforts” to stabilize at 1.5°C)

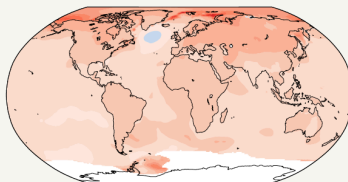
We are at a crossroads

With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture

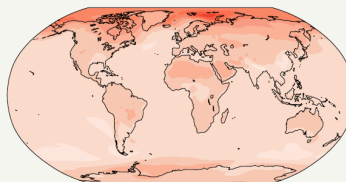
a) Annual mean temperature change (°C) at 1 °C global warming

Warming at 1 °C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

Observed change per 1 °C global warming



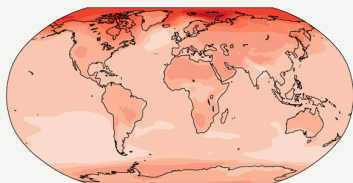
Simulated change at 1 °C global warming



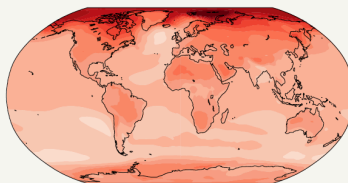
b) Annual mean temperature change (°C) relative to 1850-1900

Across warming levels, land areas warm more than oceans, and the Arctic and Antarctica warm more than the tropics.

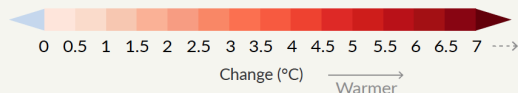
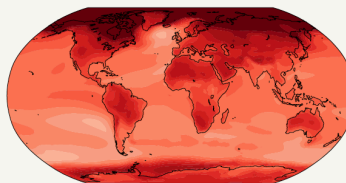
Simulated change at 1.5 °C global warming



Simulated change at 2 °C global warming



Simulated change at 4 °C global warming



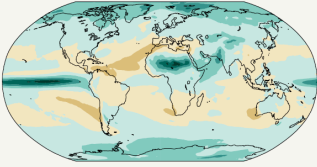
Temperature changes

The level of global warming will determine the regional changes in climate

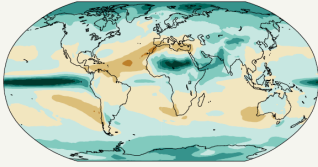
c) Annual mean precipitation change (%) relative to 1850-1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

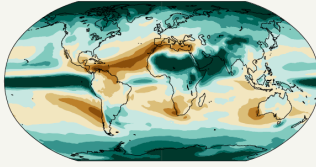
Simulated change at 1.5 °C global warming



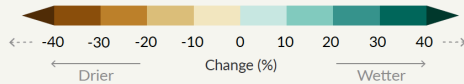
Simulated change at 2 °C global warming



Simulated change at 4 °C global warming



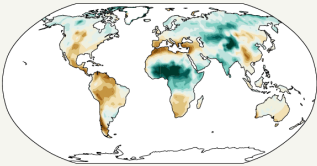
Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions



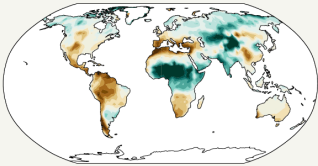
d) Annual mean total column soil moisture change (standard deviation)

Across warming levels, changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.

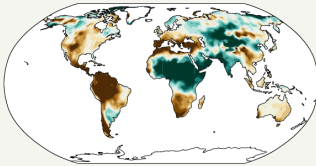
Simulated change at 1.5 °C global warming



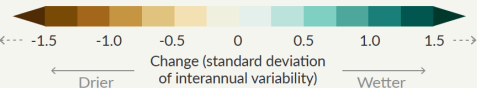
Simulated change at 2 °C global warming



Simulated change at 4 °C global warming



Relatively small absolute changes may appear large when expressed in units of standard deviation in dry regions with little interannual variability in baseline conditions



Precipitation changes

The level of global warming will determine the regional changes in climate

Soil moisture changes

Projected changes in extremes as function of global warming

Many changes in the **frequency and intensity of climate extremes become larger with increasing global warming:**

- hot extremes
- marine heatwaves
- heavy precipitation
- agricultural and ecological droughts in some regions
- proportion of intense tropical cyclones

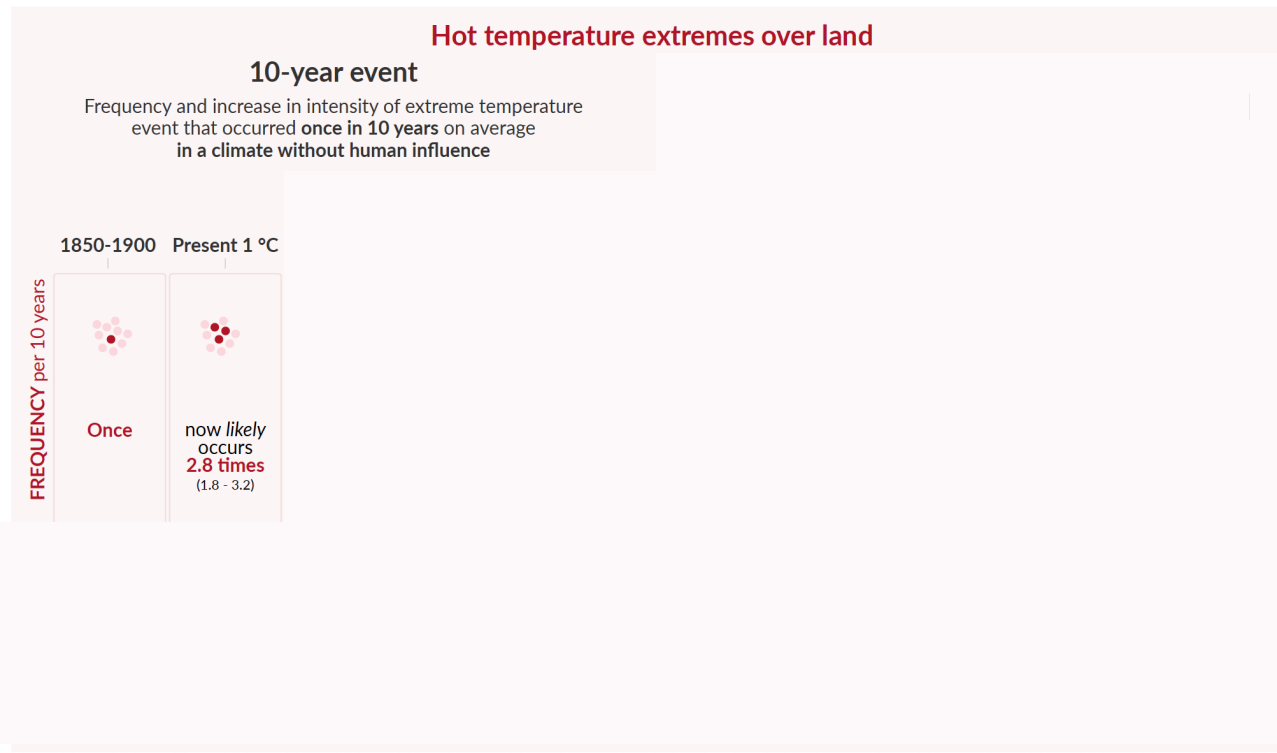
Projected changes in extremes as function of global warming

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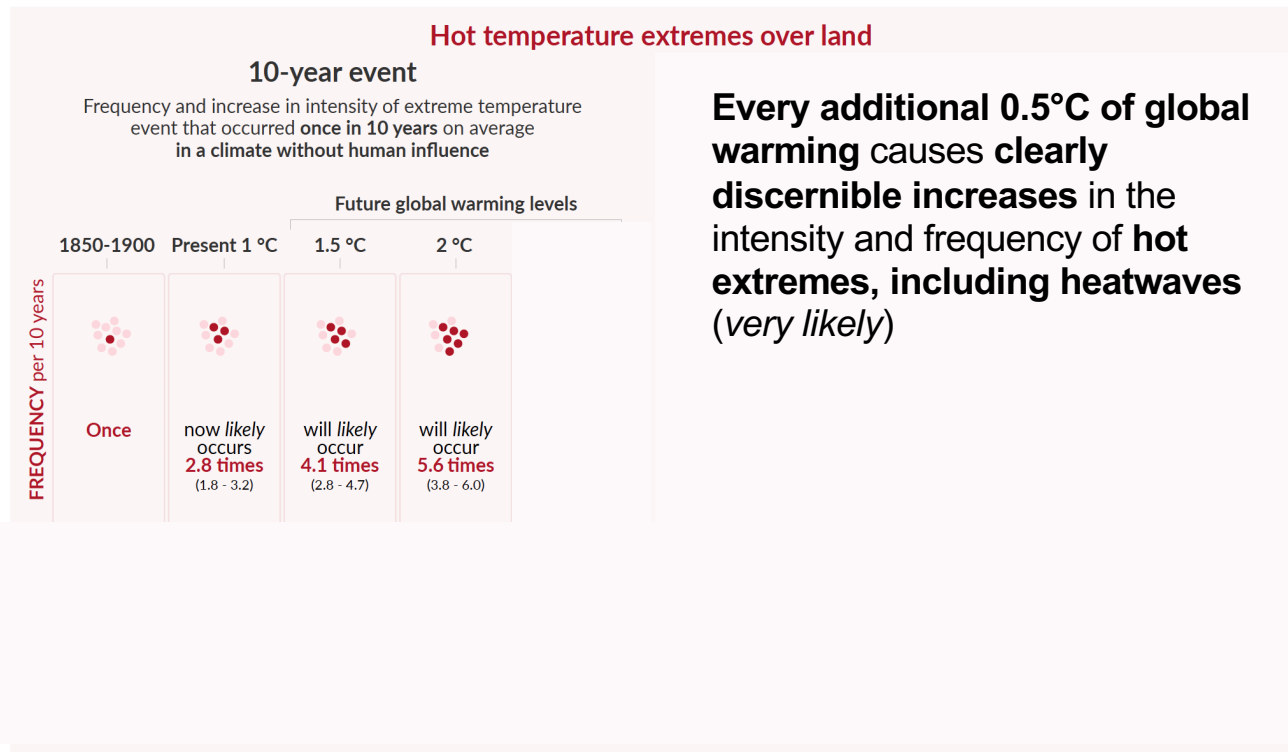
- hot extremes
- marine heatwaves
- heavy precipitation
- agricultural and ecological droughts in some regions
- proportion of intense tropical cyclones

Already much higher risks at 2°C compared to 1.5°C, as well as at 1.5°C compared to now, including some irreversible impacts

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

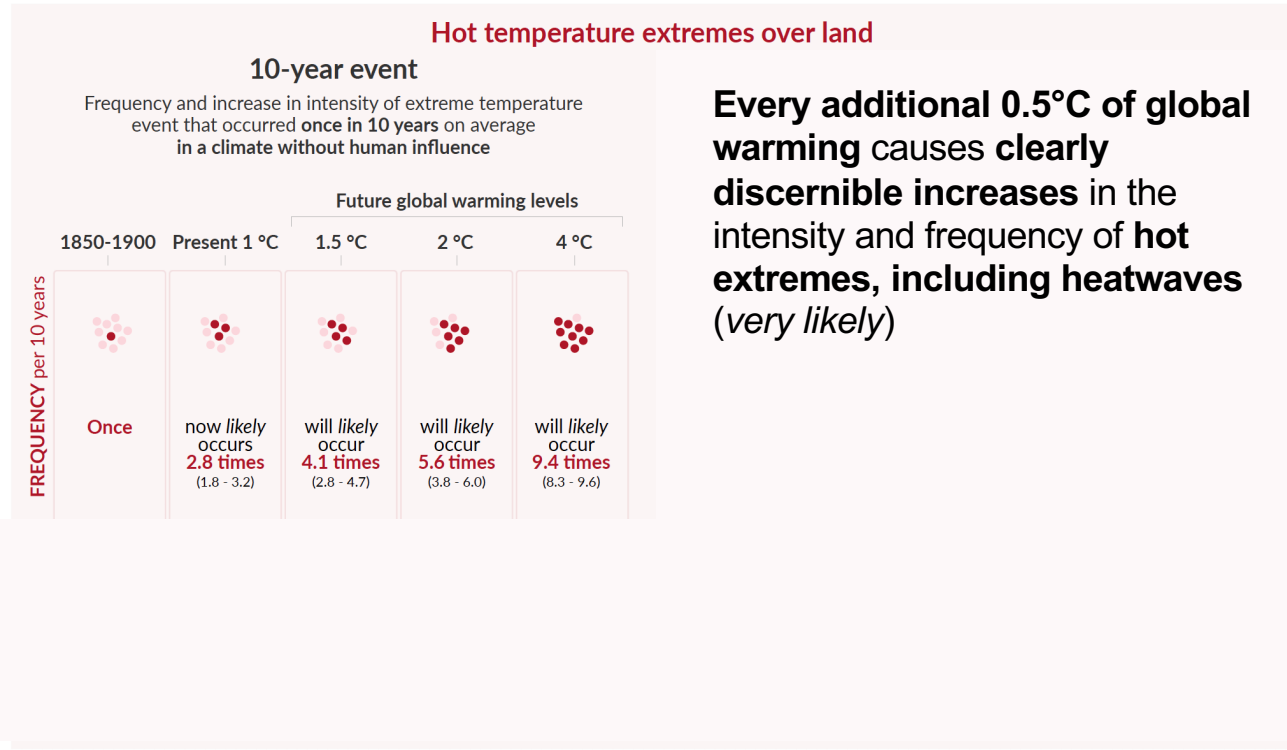


Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming



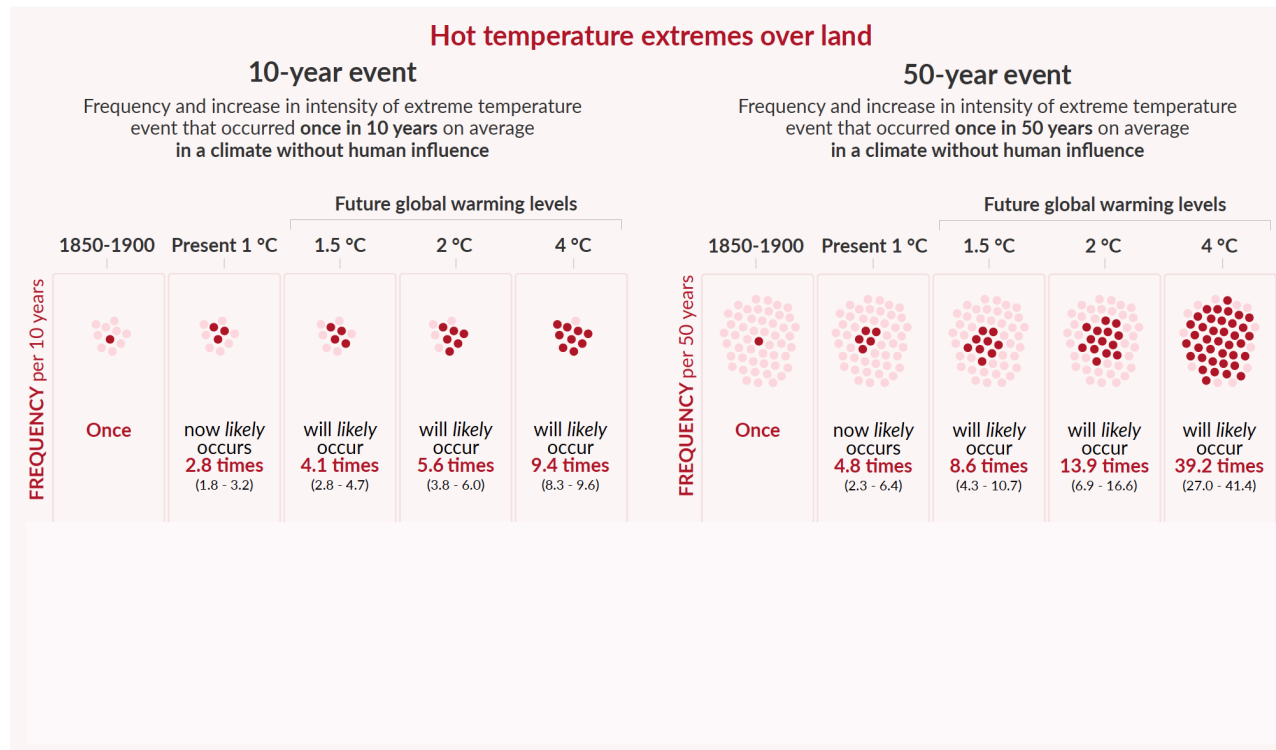
(IPCC AR6, Fig. SPM.6)

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming



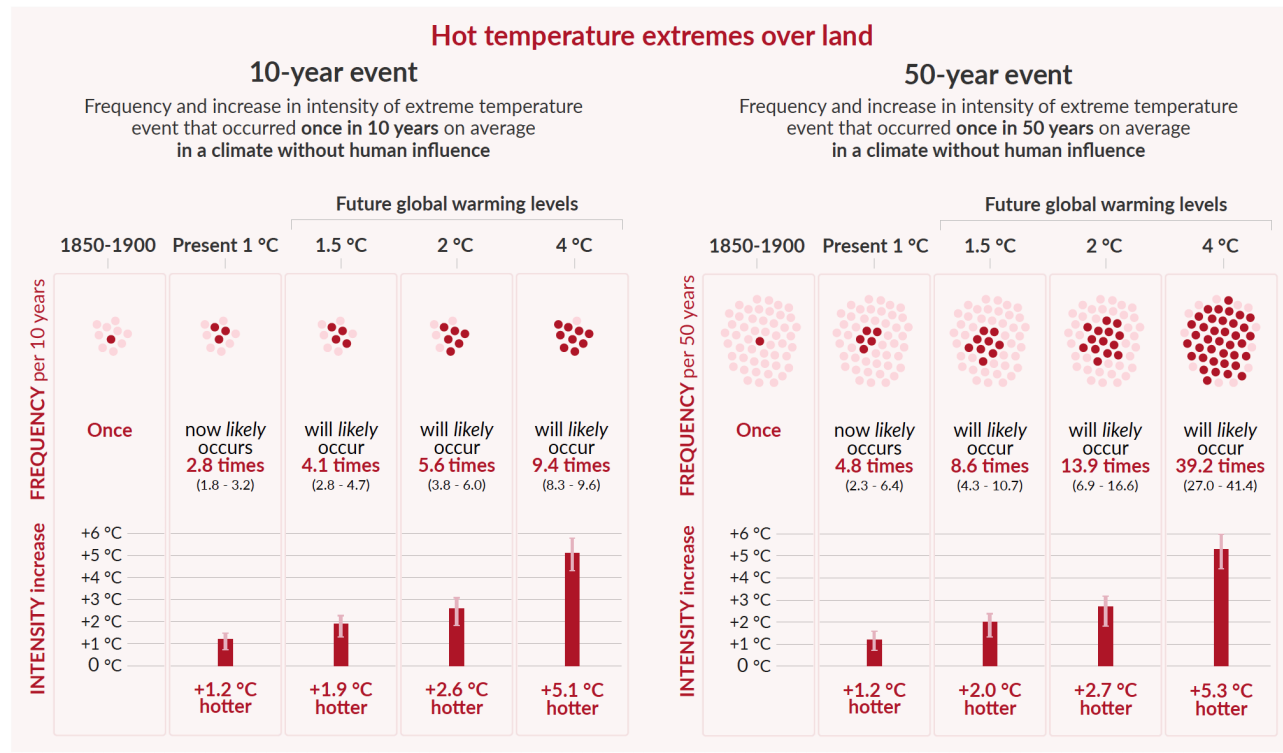
(IPCC AR6, Fig. SPM.6)

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming



Projected percentage changes in frequency are higher for rarer events (*high confidence*)

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

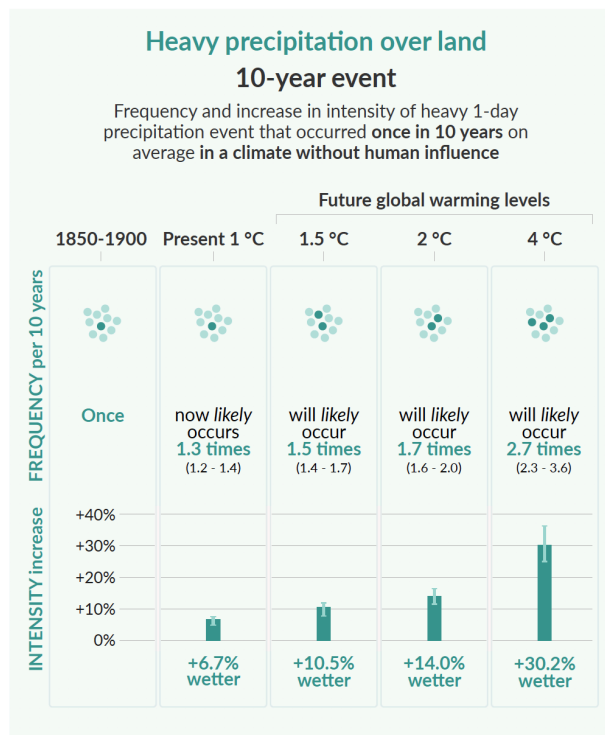


(IPCC AR6, Fig. SPM.6)

Projected percentage changes in frequency are higher for rarer events (*high confidence*)

Hot extremes on land warm more than global mean temperature

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

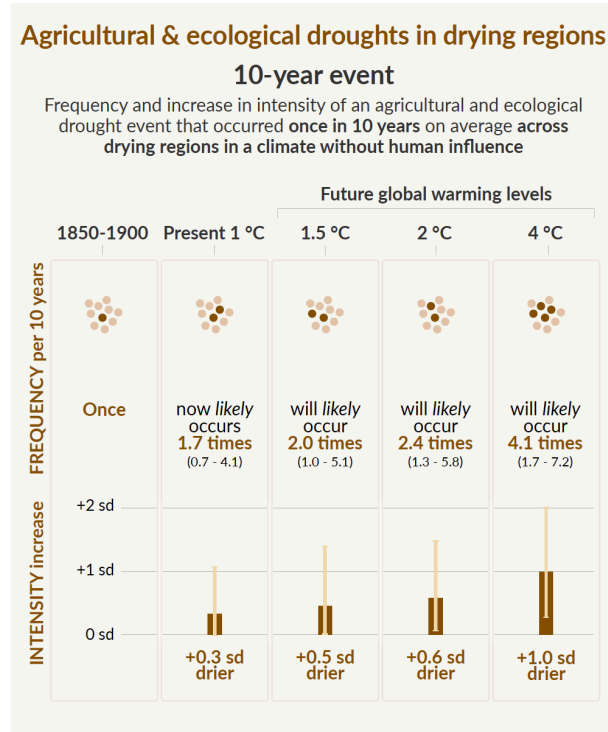
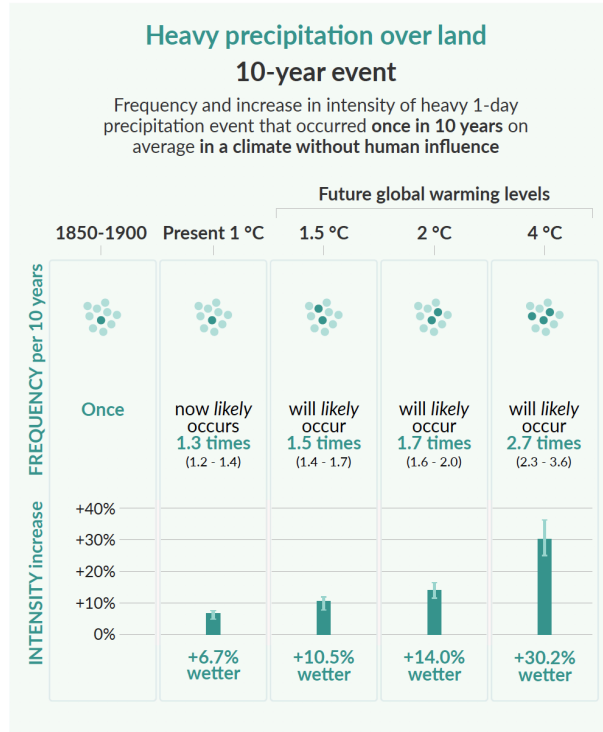


Every additional 0.5°C of global warming causes clearly

discernible increases in:

- **heavy precipitation** (*high confidence*)

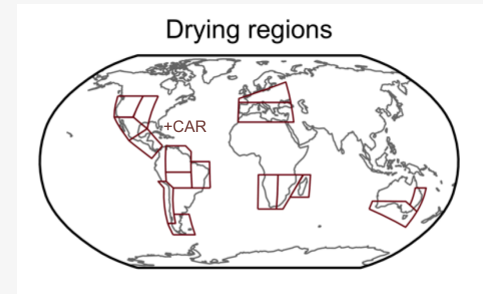
Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming



Every additional 0.5°C of global warming causes clearly **discernible increases** in:

- **heavy precipitation** (*high confidence*)
- **agricultural and ecological droughts** in some regions (*high confidence*)

Regions with assessed drying at 2°C of global warming

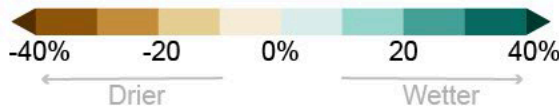
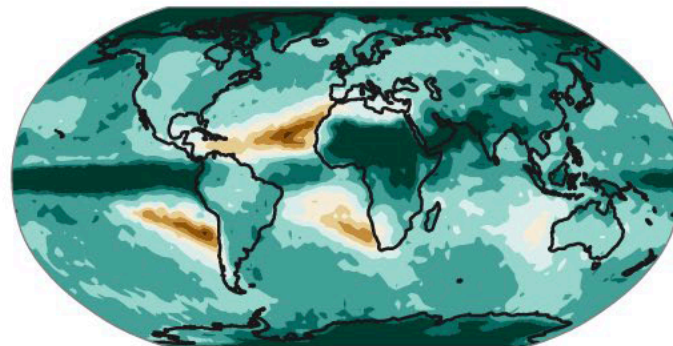
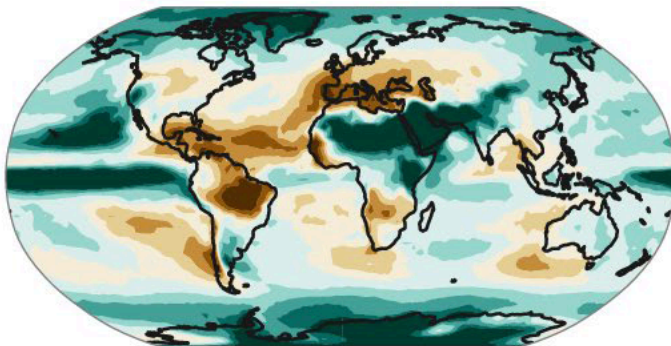


Changes in mean precipitation vs extreme precipitation (for ca. 4°C of global warming)

Mean precipitation

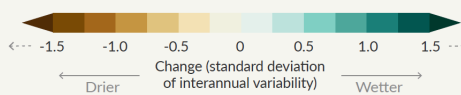
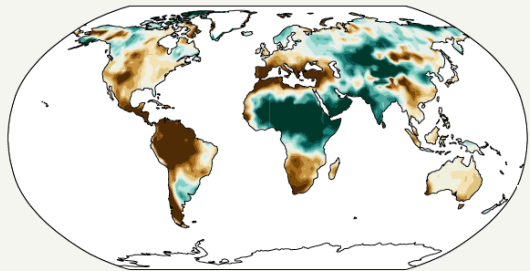
Extreme precipitation (Rx1day)

Future changes
in precipitation
averages and
extremes can be
very different



Soil moisture

Simulated change at 4 °C global warming



Both too much and too little water on continents

(IPCC AR6, Ch11)

Compound events:

- **With further global warming, every region is projected to increasingly experience multiple changes in climatic impact-drivers, including extremes**

Compound events:

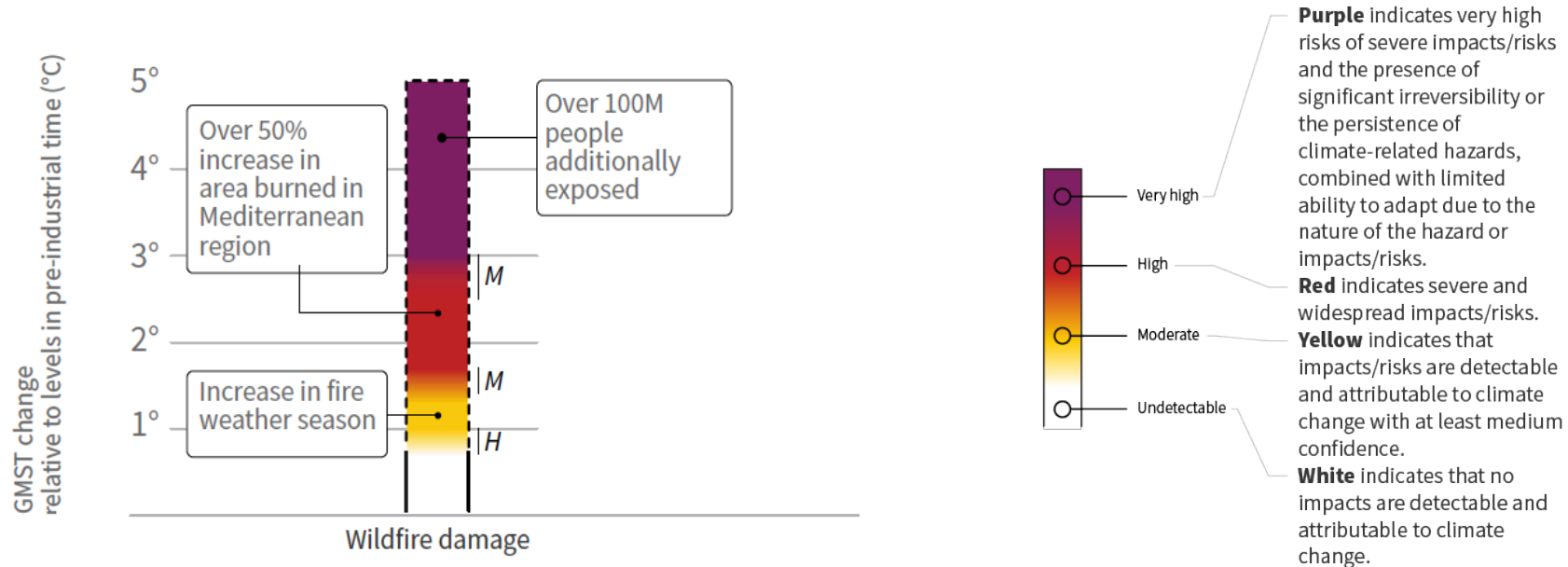
- With further global warming, every region is projected to increasingly experience multiple changes in climatic impact-drivers, including extremes
- Many regions are projected to experience an increase in the probability of **compound events** with higher global warming (*high confidence*):
 - **Concurrent heatwaves and droughts** are *likely* to become more frequent
 - Further increases of **fires** and **compound flooding** (*high confidence*)



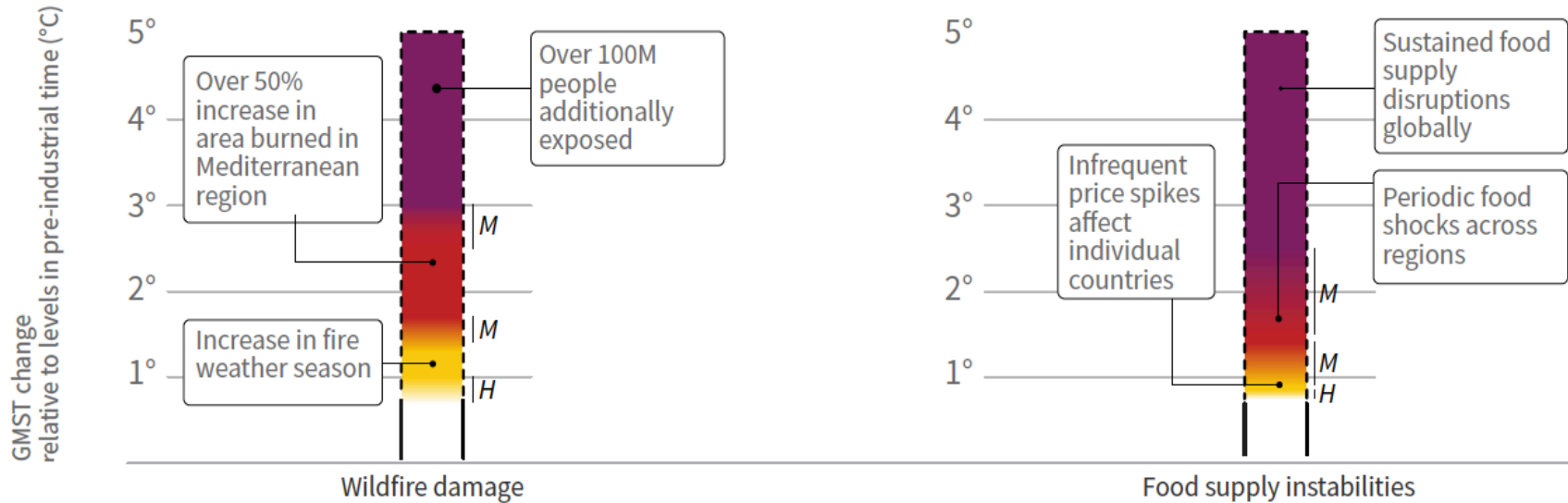
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- Many regions are projected to experience an increase in the probability of **compound events** with higher global warming (*high confidence*):
 - **Concurrent heatwaves and droughts** are *likely* to become more frequent
 - Further increases of **fires** and **compound flooding** (*high confidence*)
 - **Concurrent extremes at multiple locations** become more frequent, including in **crop-producing areas**, at 2°C and above compared to 1.5°C global warming (*high confidence*)





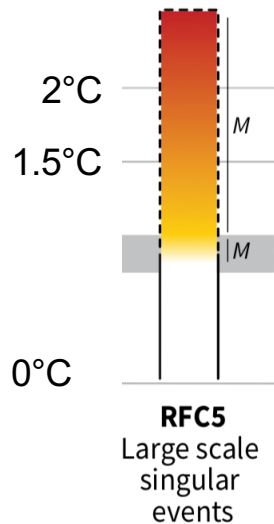
(IPCC Land report: <https://www.ipcc.ch/srcc1>)



(IPCC Land report: <https://www.ipcc.ch/srccl>)

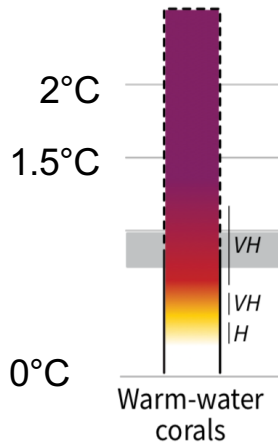
High risks for wildfire damages and food supply instabilities already above 1.5°C

- More risks of hitting
global tipping points
between 1.5°C and 2°C



(IPCC SR15, 2018)

- Risks to coral reefs



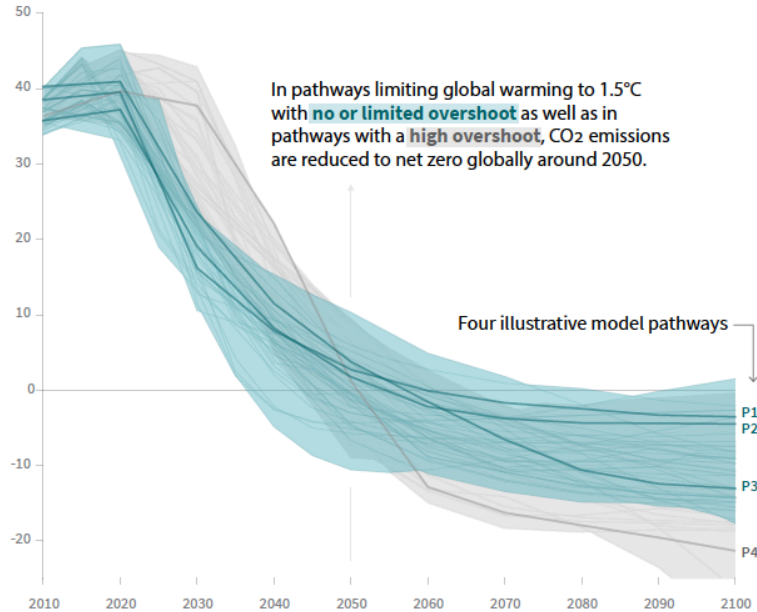
- Irreversible impacts to biodiversity** associated with higher global warming:
 - coral reefs: losses of 70-90% at 1.5°C, losses of >99% at 2°C
 - tripling of insects and doubling of plants and vertebrates which lose more than half of their geographic range at 2°C vs 1.5°C of global warming



(IPCC SR15, 2018)

Global total net CO₂ emissions

Billion tonnes of CO₂/yr



(IPCC SR15)

Stabilization to ~1.5°C requires changes which are unprecedented in terms of scale:

- **Immediate reduction of CO₂ emissions on global scale (until 2030: 50% of 2010)**
- **Net-zero CO₂ emissions at the latest in 2040 (66% probability) – 2050 (50% probability)**
- **“Negative emissions”** after reaching net-zero CO₂: **At most 10%** of present-day emissions

Working Group I – The Physical Science Basis

- 7-12 years of remaining CO₂ emissions for 1.5°C limit at current emissions level
- Scenarios with stabilization at 1.5°C: -40-60% decrease in CO₂ emissions until 2030
- Need between 5-7.5% decrease of CO₂ emissions per year

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; <i>likely</i> range)	2390 (± 240; <i>likely</i> range)

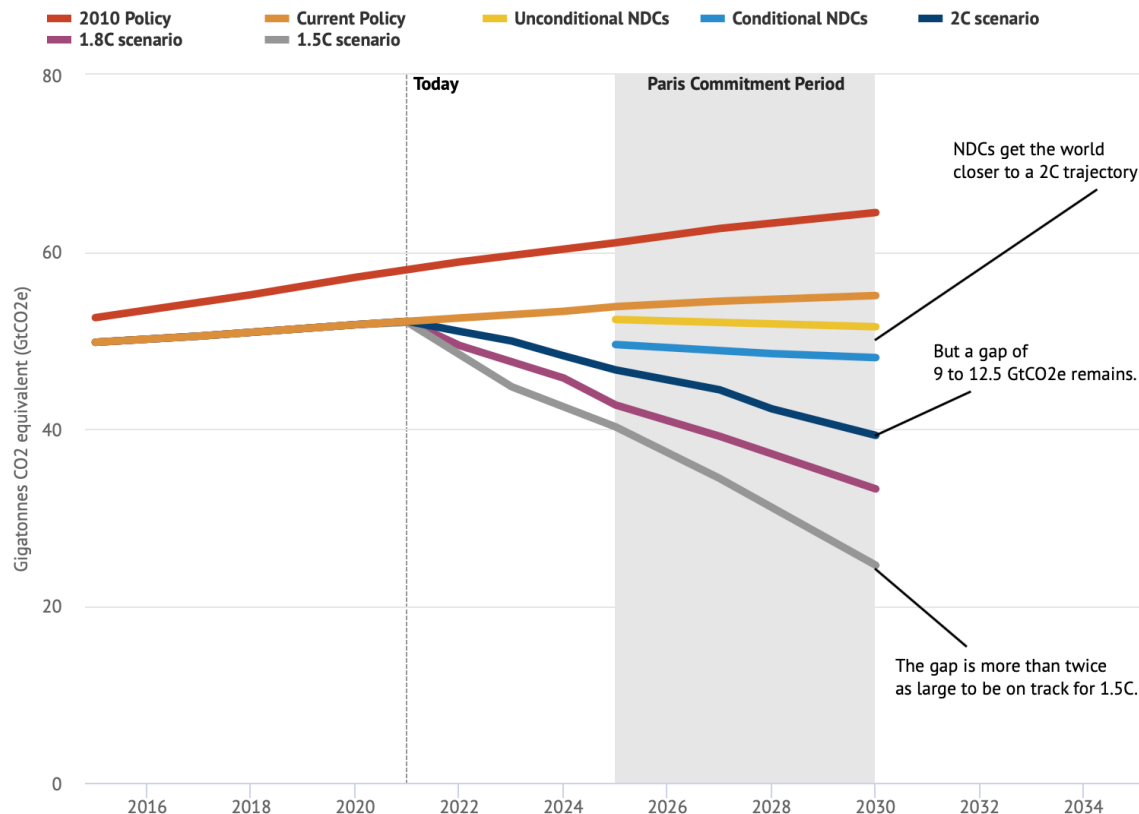
Approximate global warming relative to 1850–1900 until temperature limit (°C)*(1)	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 (GtCO ₂)					Variations in reductions in non-CO ₂ emissions*(3)
		<i>Likelihood of limiting global warming to temperature limit*(2)</i>					
		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

We are in a climate crisis

**Yearly emissions:
~ 40 GtCO₂**

(IPCC AR6)

A large gap remains between 2030 commitments and Paris Agreement goals



Based on 2030 targets: we are on a trajectory towards 2.4°C

We are not on track

<https://www.carbonbrief.org/analysis-do-cop26-promises-keep-global-warming-below-2c>

We are in a climate crisis:

- We already have more than 1.1°C of global warming, if we don't decrease CO_2 emissions immediately, 1.5°C will be out of reach
- Many extreme events are become more intense and frequent, and we are starting to see events which are without precedent
- The Mediterranean region is among the most affected regions of the world. It is in particular a hot spot for observed and projected drying.

What's next?

- First step: Require $\sim 50\%$ decrease in CO_2 emissions until 2030, ca. 5-7.5% per year from now on; **we are not on track**
- World countries need to submit more ambitious CO_2 mitigation targets at COP27
- **We need action, not only words**

EVERY ACTION MATTERS
EVERY BIT OF WARMING MATTERS
EVERY YEAR MATTERS
EVERY CHOICE MATTERS

Thank you!

