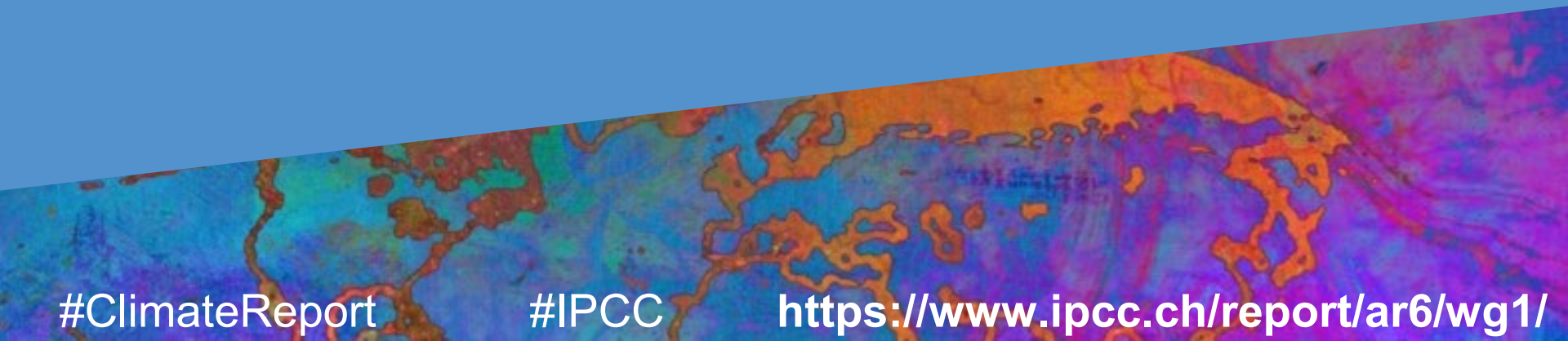
SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

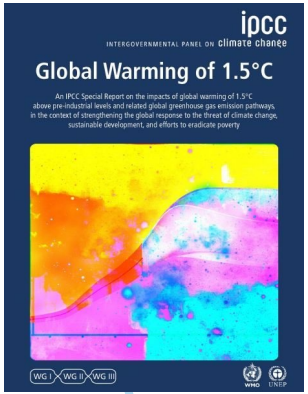
ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

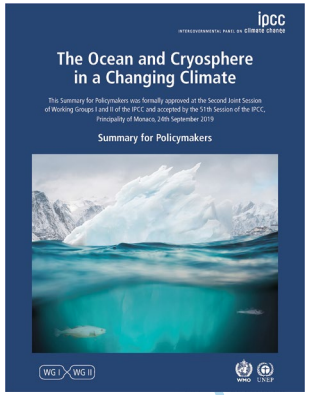
SBSTA: 4 November 2021

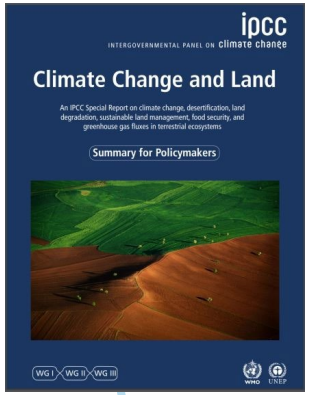
AR6 Climate Change 2021: The Physical Science Basis

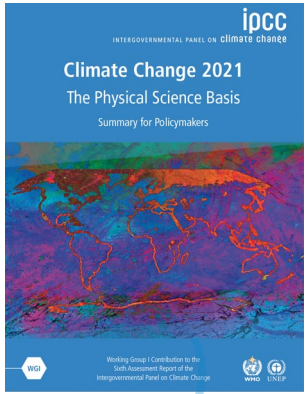


#ClimateReport #IPCC **https://www.ipcc.ch/report/ar6/wg1/**









WGII

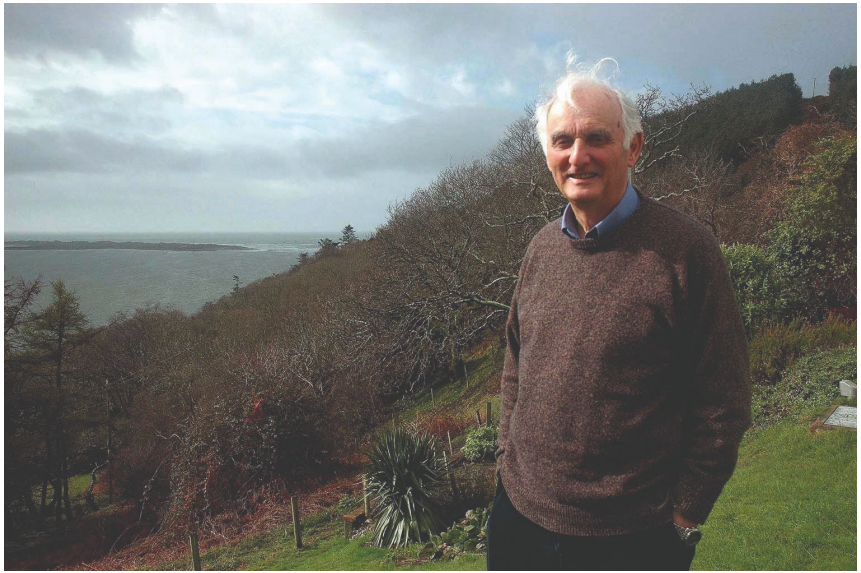
WGIII

Synthesis Report

Dedication to Sir John Houghton

30 December 1931 – 15 April 2020

WGI Chair and Co-Chair for the first three assessment reports (1988 - 2002)



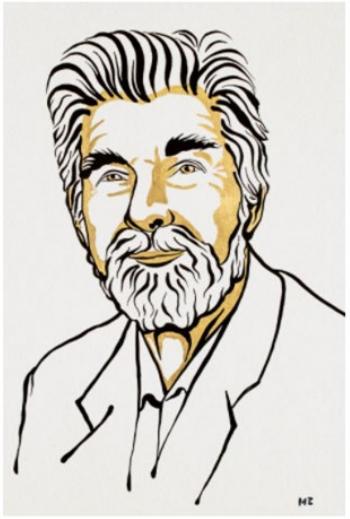
The Nobel Prize in Physics 2021

"for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"

Ill. Niklas Elmehed © Nobel Prize Outreach

Syukuro Manabe

Prize share: 1/4



Ill. Niklas Elmehed © Nobel Prize Outreach

Klaus Hasselmann

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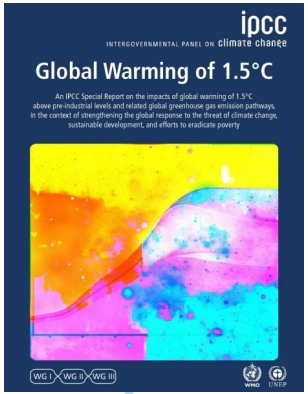

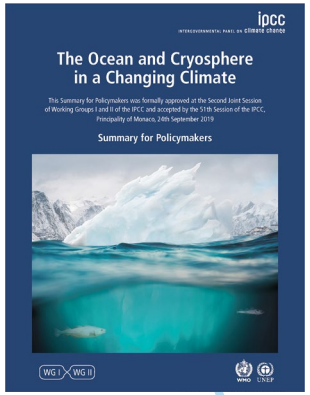

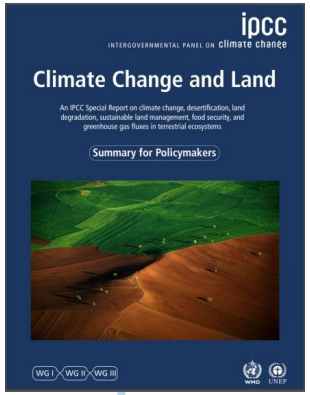

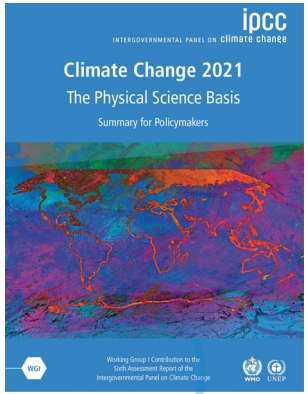

WGII

WGIII

Synthesis Report

Author Team

234 authors from **65** countries

28% women, **72%** men

63% first-time IPCC authors

14,000 scientific publications assessed

Review Process

78,000+ review comments

46 countries commented on Final Government Distribution

1st online approval

186h zoom meetings

200+ delegates

Climate Report key findings

- Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years.
- It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.
- Climate change is already affecting every region on Earth, in multiple ways. The changes we experience will increase with further warming.
- There's no going back from some changes in the climate system. However, some changes could be slowed and others could be stopped by limiting warming.
- Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C and even 2°C will be beyond reach.
- To limit global warming, strong, rapid, and sustained reductions in CO2, methane, and other greenhouse gases are necessary. This would not only reduce the consequences of climate change but also improve air quality.

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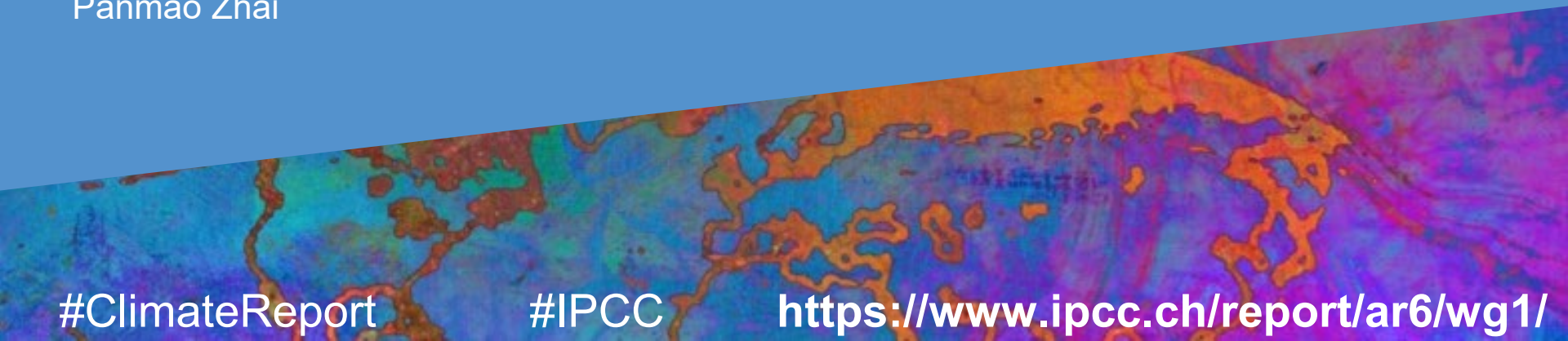
Valérie Masson-Delmotte
Panmao Zhai



#ClimateReport #IPCC **https://www.ipcc.ch/report/ar6/wg1/**

Structure of the session

10.30-13.30 UTC

Introduction

A. The Current State of Climate

Questions & answers

B. Possible Climate Futures

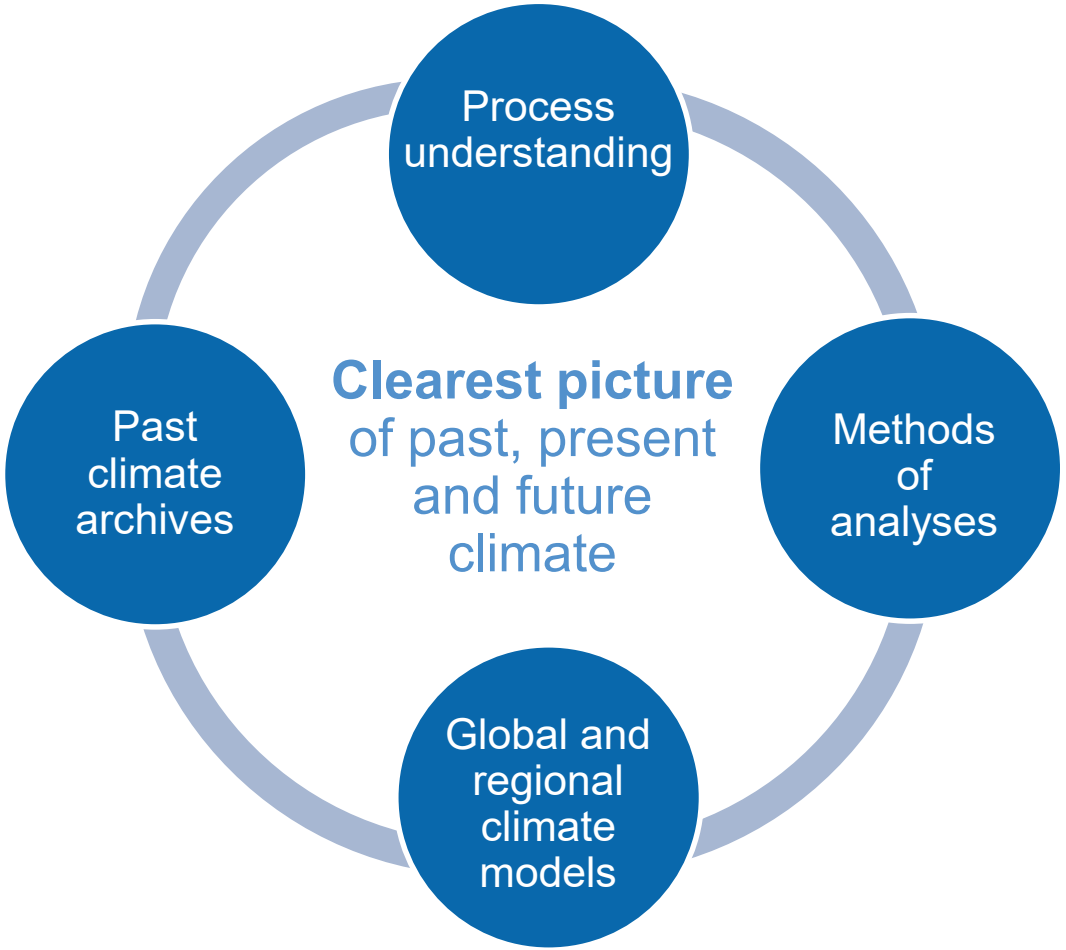
Questions & answers

C. Climate Information for Risk Assessment and Regional Adaptation

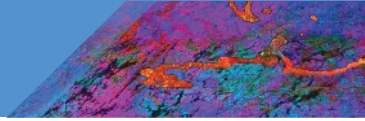
Questions & answers

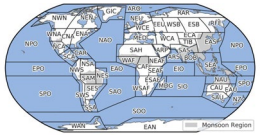
D. Limiting Climate Change

Questions & answers



evidence from over
14,000 publications
assessed in the report





SUMMARY FOR POLICYMAKERS (SPM)

TECHNICAL SUMMARY (TS)

FULL REPORT

- Large-scale climate change
- Understanding the climate system response
- Regional climate information

INTERACTIVE ATLAS

FREQUENTLY ASKED QUESTIONS (FAQs)

REGIONAL FACT SHEETS

- Africa
- Asia
- Australasia
- Central and South America
- Europe
- Mountains
- North and Central America
- Ocean
- Polar regions
- Small Islands
- Urban areas

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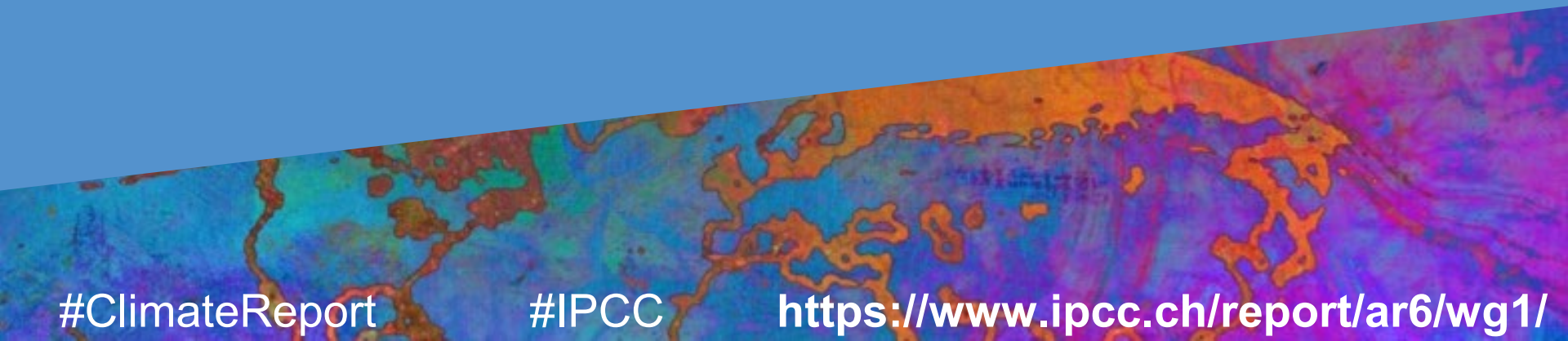
A. Current state of the climate

Valérie Masson-Delmotte
Panmao Zhai

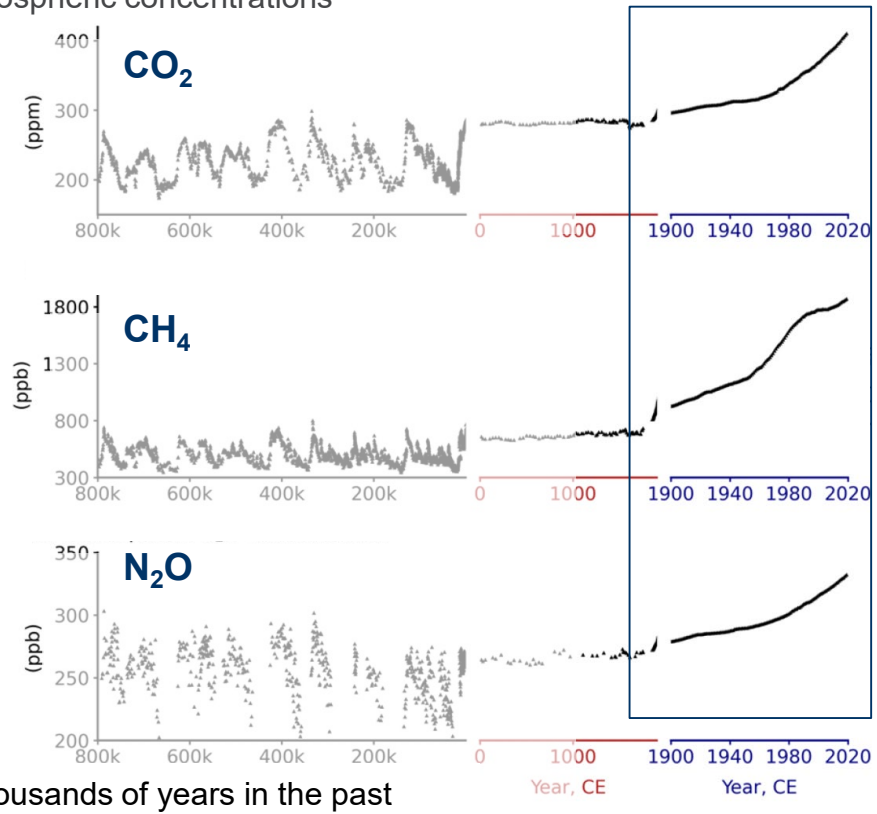


Section A - Current state of the climate

- Recent changes in the climate are widespread, rapid, and intensifying. They are unprecedented in thousands of years.
- Human influence on the climate is unequivocal.
- Climate change is already affecting every region on Earth, in multiple ways.
- Climate change is making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.

Human influence on climate is unequivocal

Atmospheric concentrations



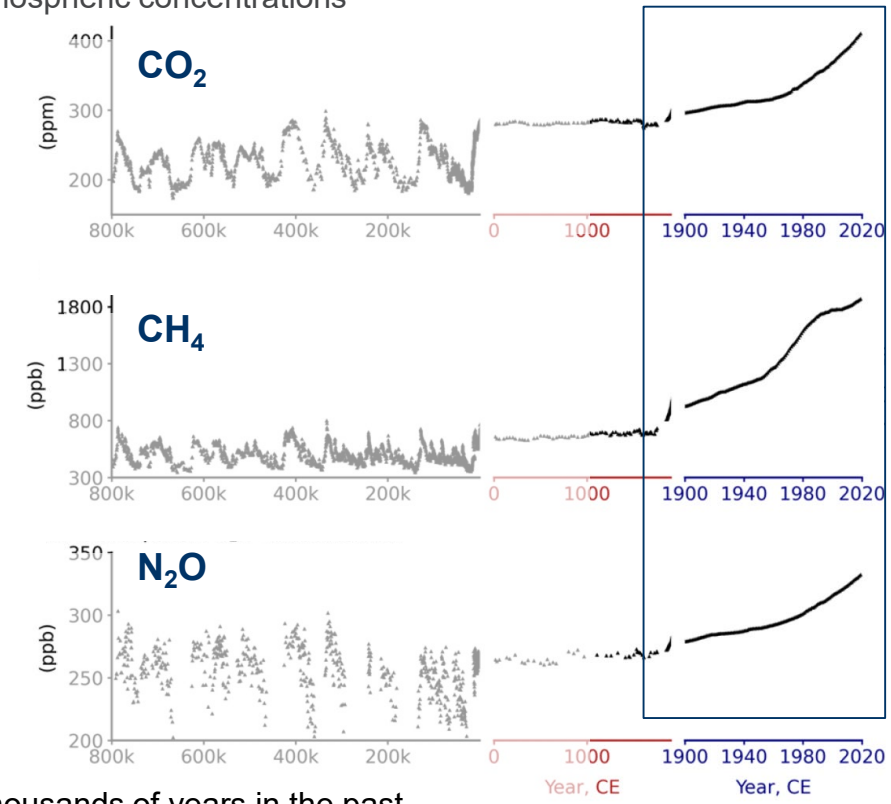
Observed increases in well-mixed **greenhouse gas (GHG)** concentrations since ~1750 are unequivocally caused by **human activities**

Emissions in the last decade reached the highest levels in human history

Figure 5.4

Human influence on climate is unequivocal

Atmospheric concentrations



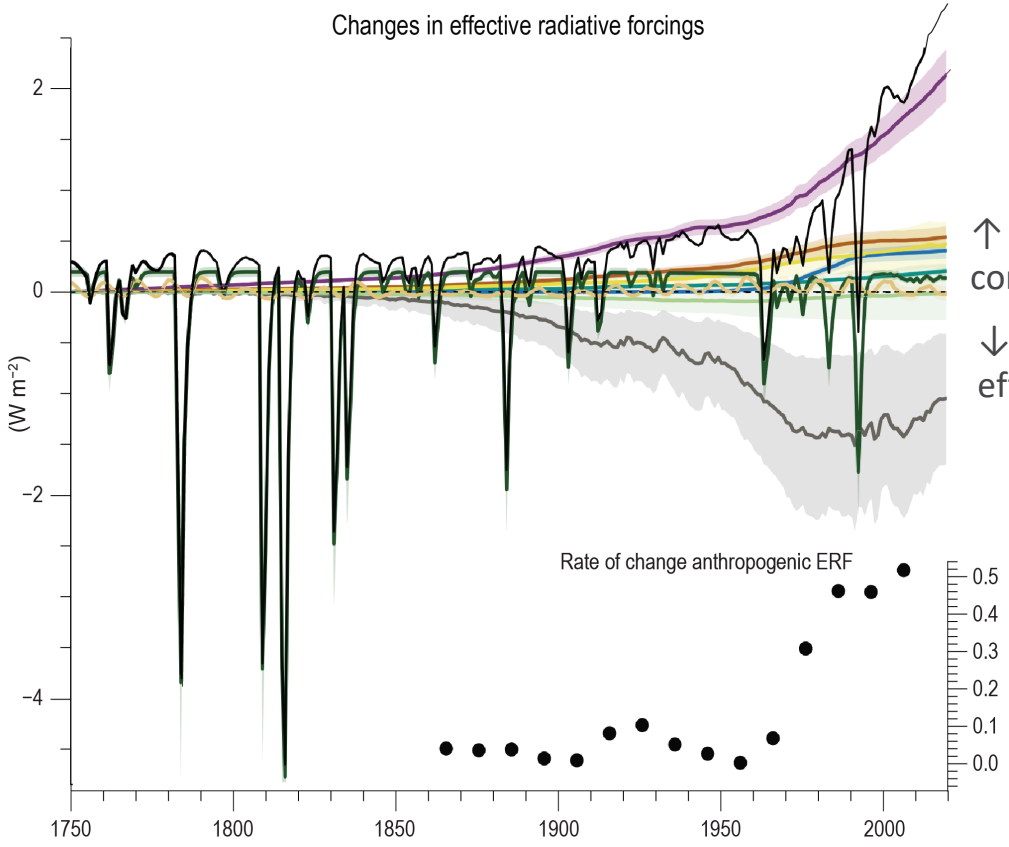
Concentrations in 2019

- 410 ppm CO_2 (+47%)
- 1866 ppb CH_4 (+156%)
- 332 ppb N20 (+23%)

Figure 5.4

Human-caused radiative forcing is increasing

Carbon dioxide (CO_2)
Methane (CH_4)
Nitrous oxide (N_2O)
Ozone (O_3)
Halogenated gases
Tropospheric Aerosol
Other anthropogenic
Volcanic
Solar
Total



↑ greenhouse gas concentrations

↓ global cooling effect of aerosols

Change in effective radiative forcings (W/m^2)

Rate (W/m^2 per decade)

Figure 2.10

Human influence causes heating of the climate system

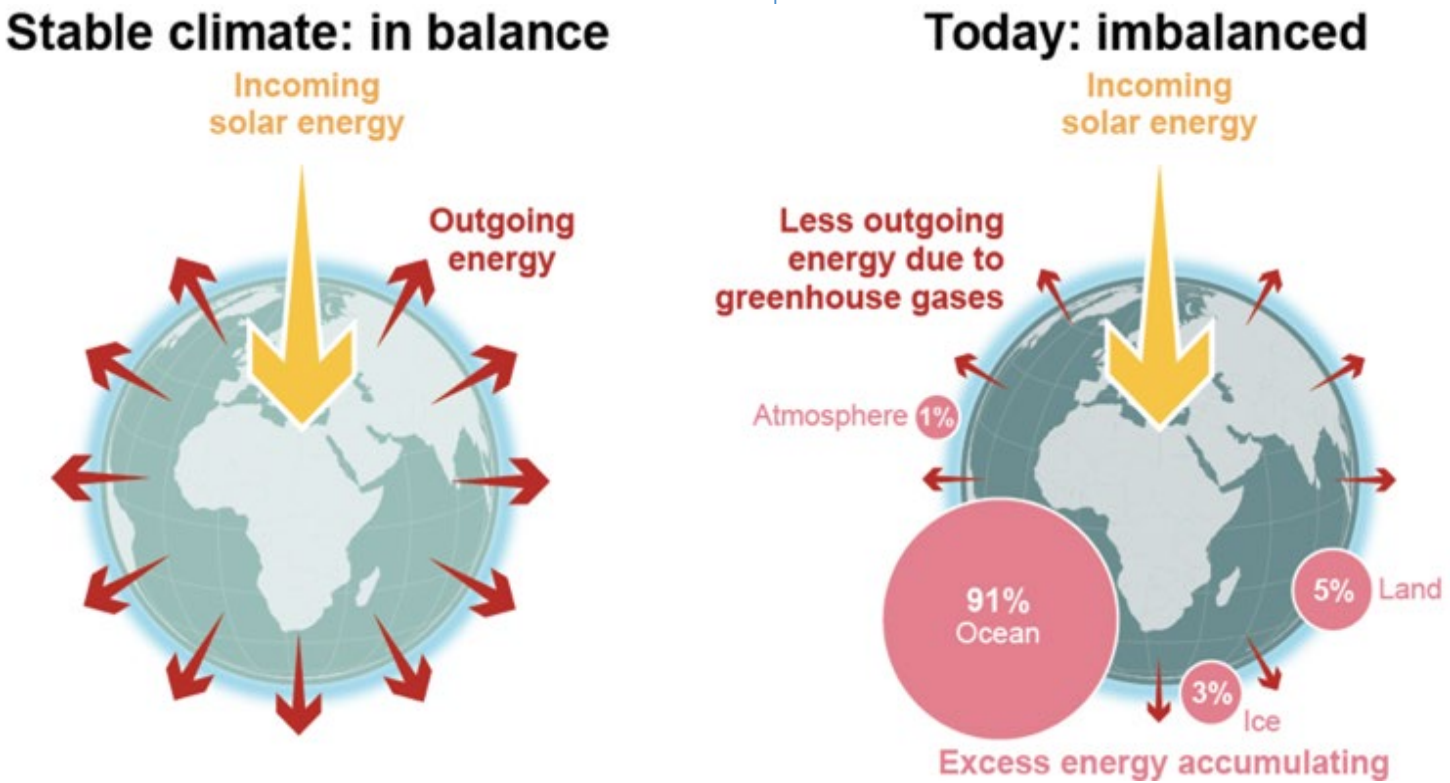


Figure FAQ7.1

Changes are widespread, rapid, and intensifying

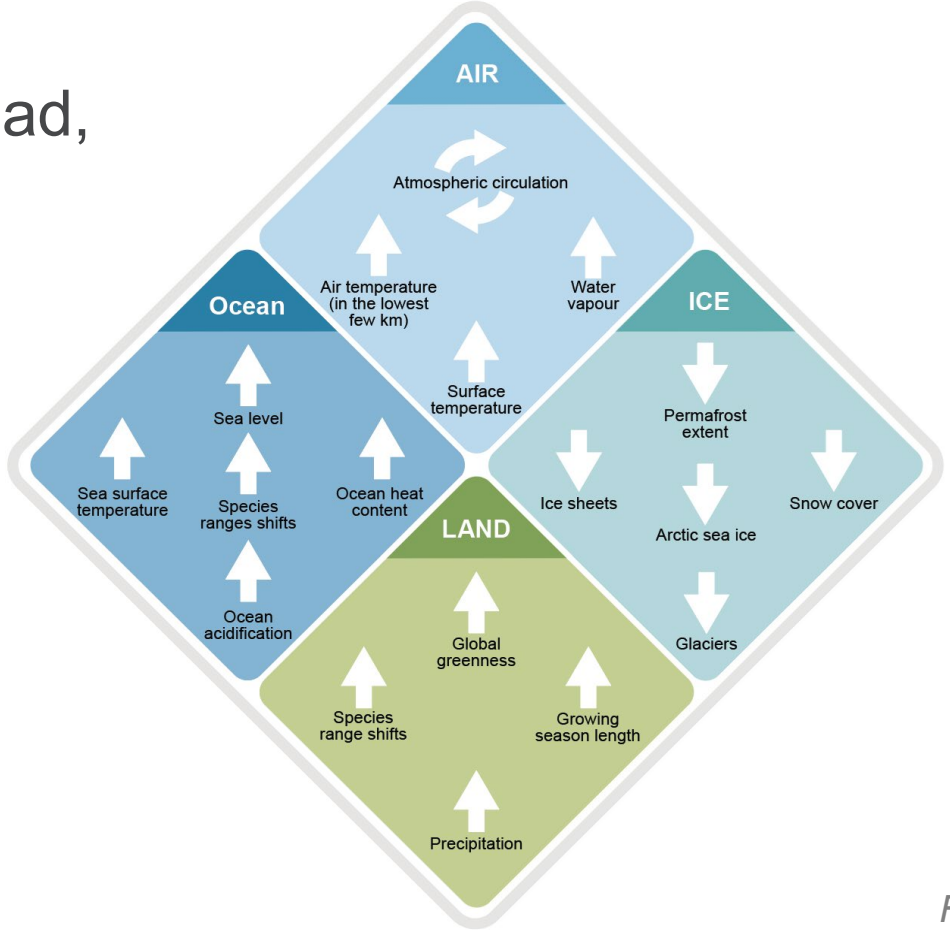


Figure FAQ2.2

These changes are unprecedented

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**

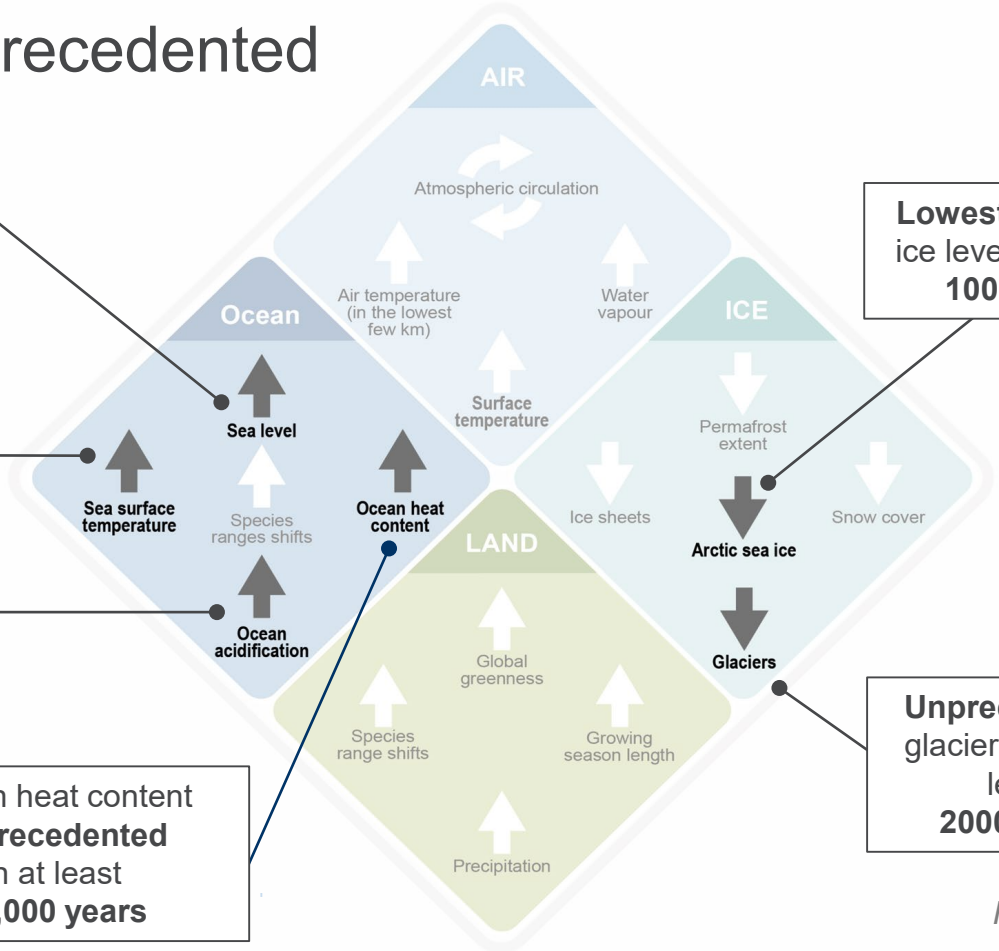
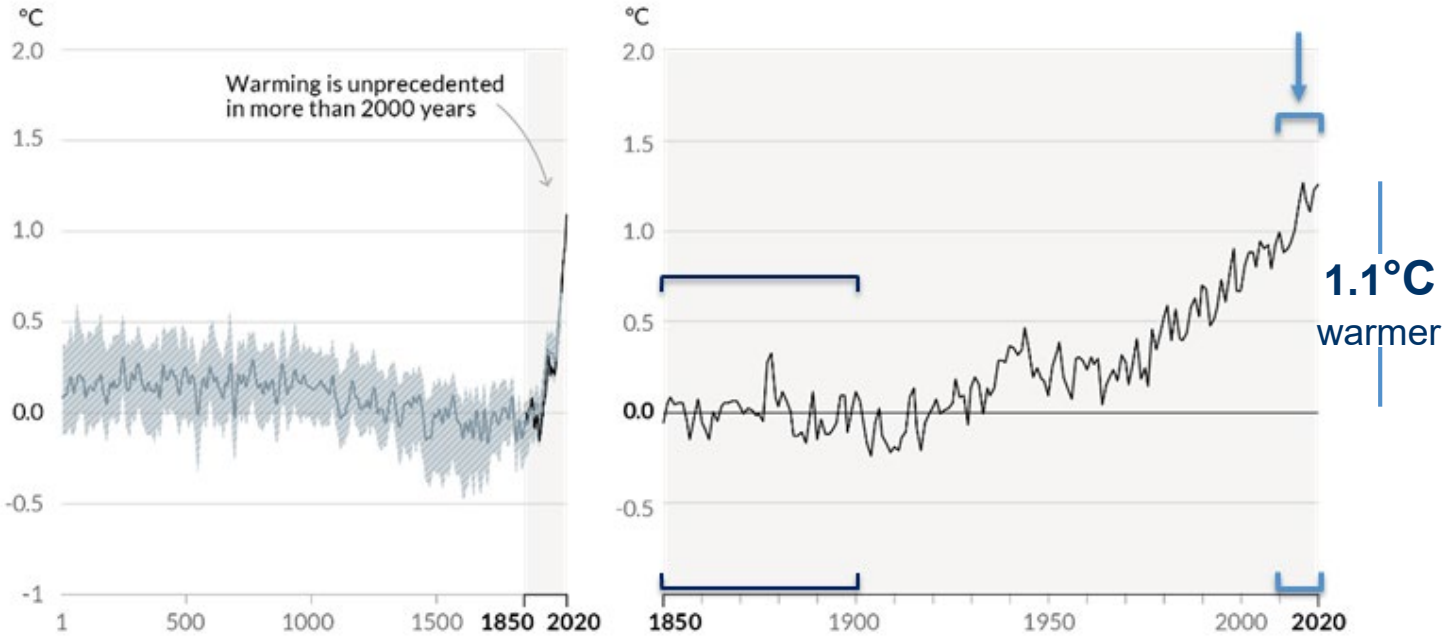


Figure FAQ2.2

The Earth has warmed by 1.1ºC
Warming is unprecedented in more than 2000 years

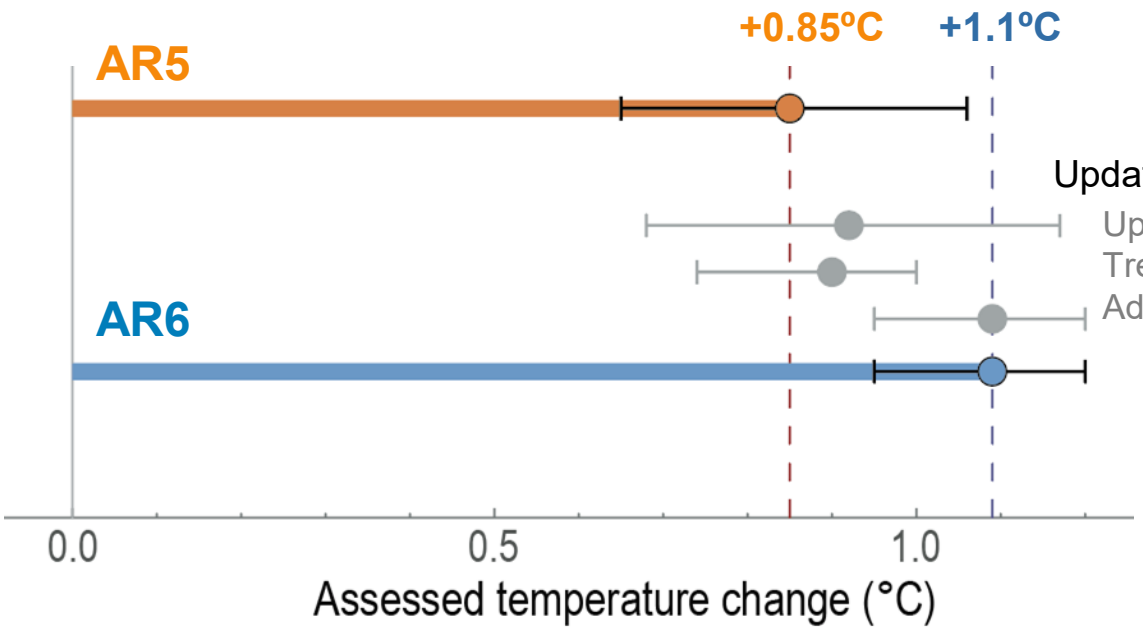
Changes in global surface temperature relative to 1850-1900



Adapted from Figure SPM.1

Updated global temperature estimates since AR5

Change in assessed historical global surface temperature estimates since AR5



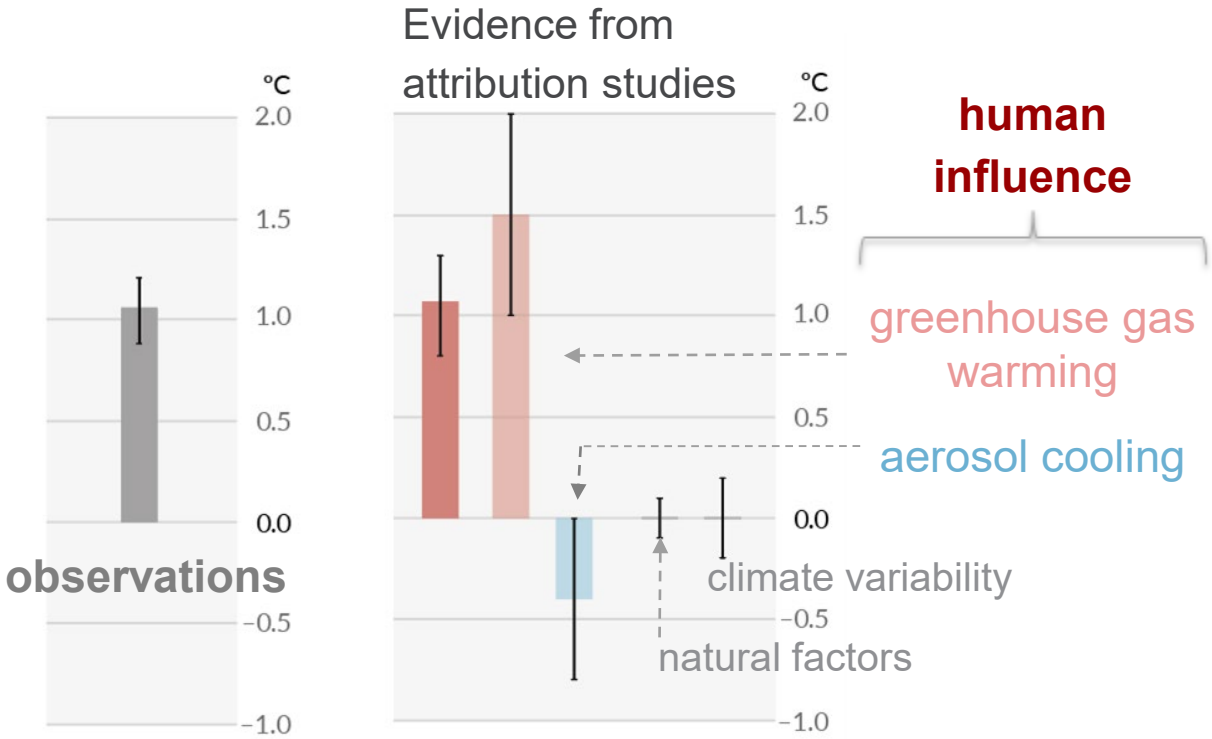
Updates from AR5 to AR6

Update of data products
Trend method
Additional years

Last decade warmer than all prior decades on record

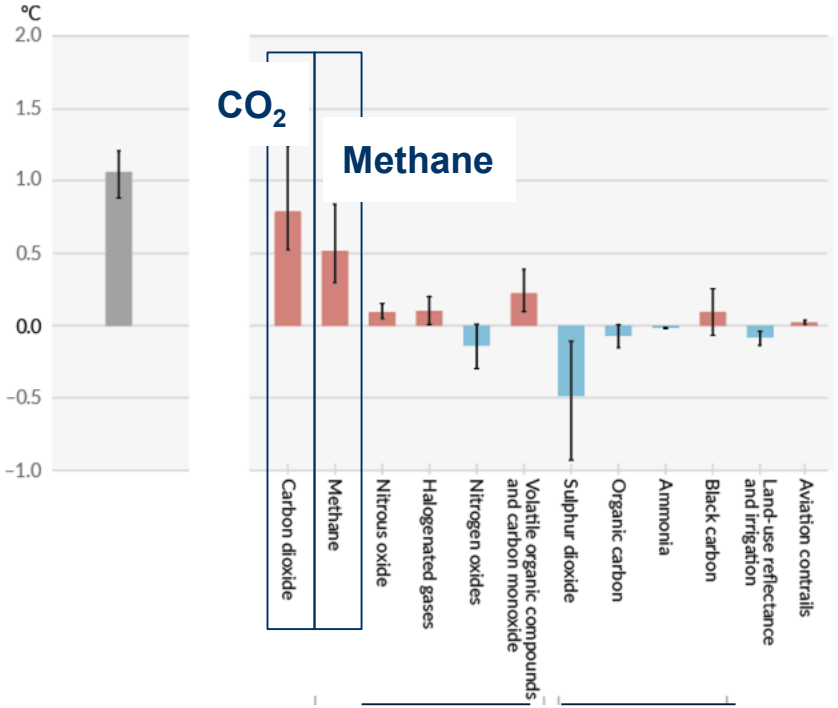
Adapted from Cross-Chapter box 2.3, Figure 1

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling



Adapted from Figure SPM.2

Improved understanding of the role of each individual component of human influence



Evidence from radiative forcing and climate sensitivity studies

Adapted from Figure SPM.2

Widespread changes are attributed to human influence

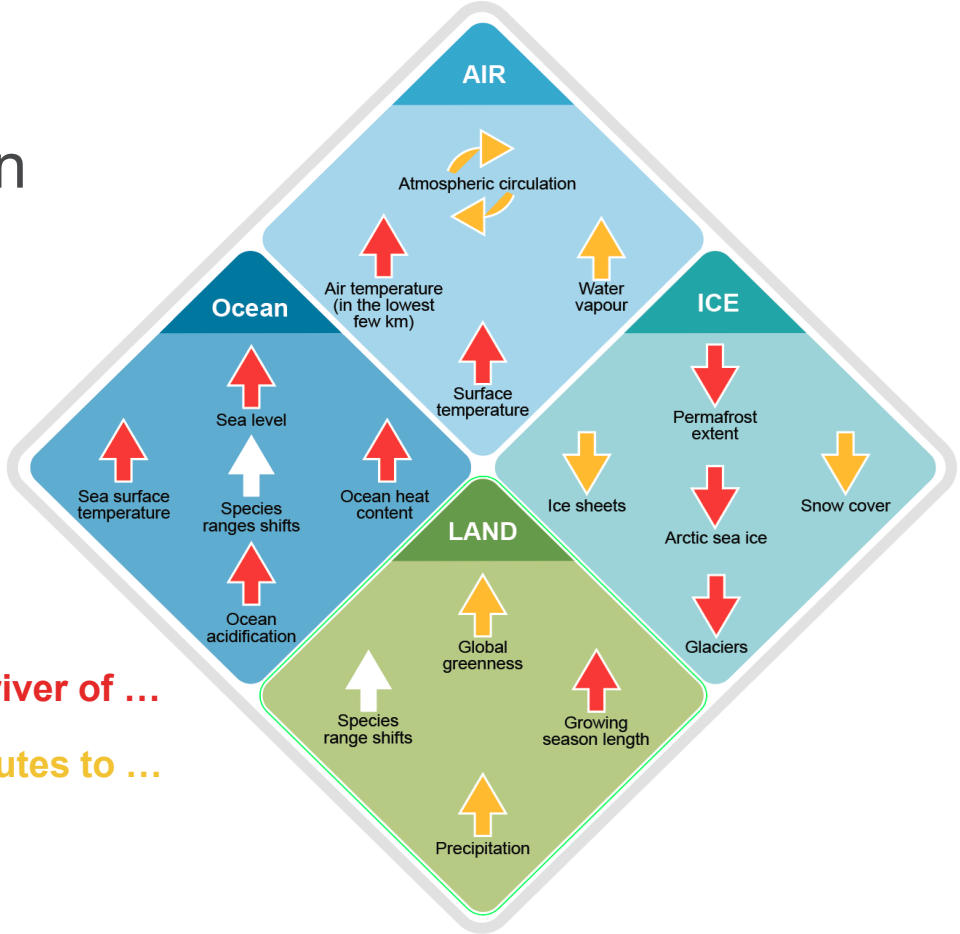


Figure FAQ2.2

Human-induced changes are increasingly apparent at regional and local scales

Change in surface air temperature
human-caused & natural
natural only

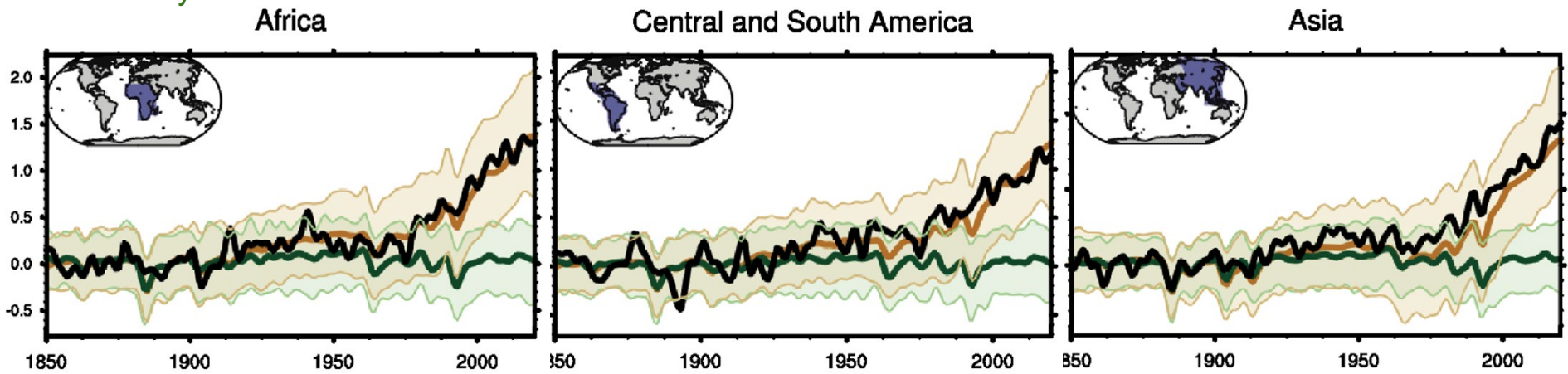
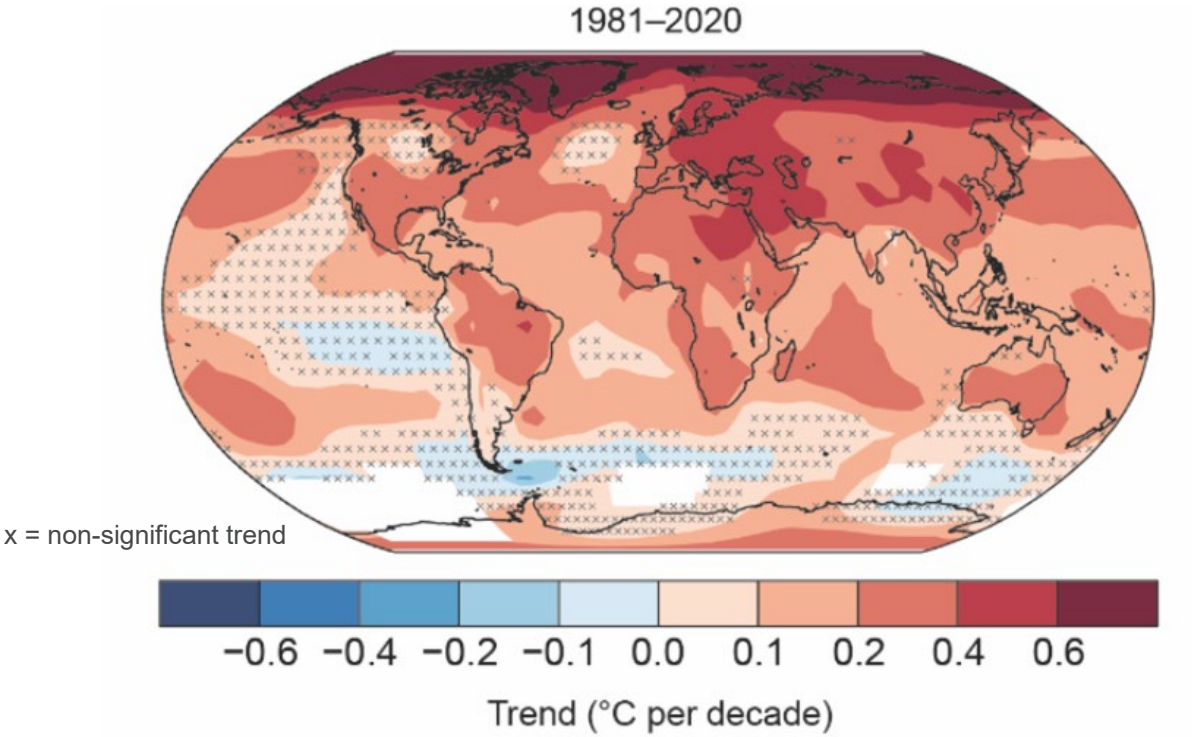


Figure TS.7

Observed warming is stronger over land than ocean and strongest in the Arctic

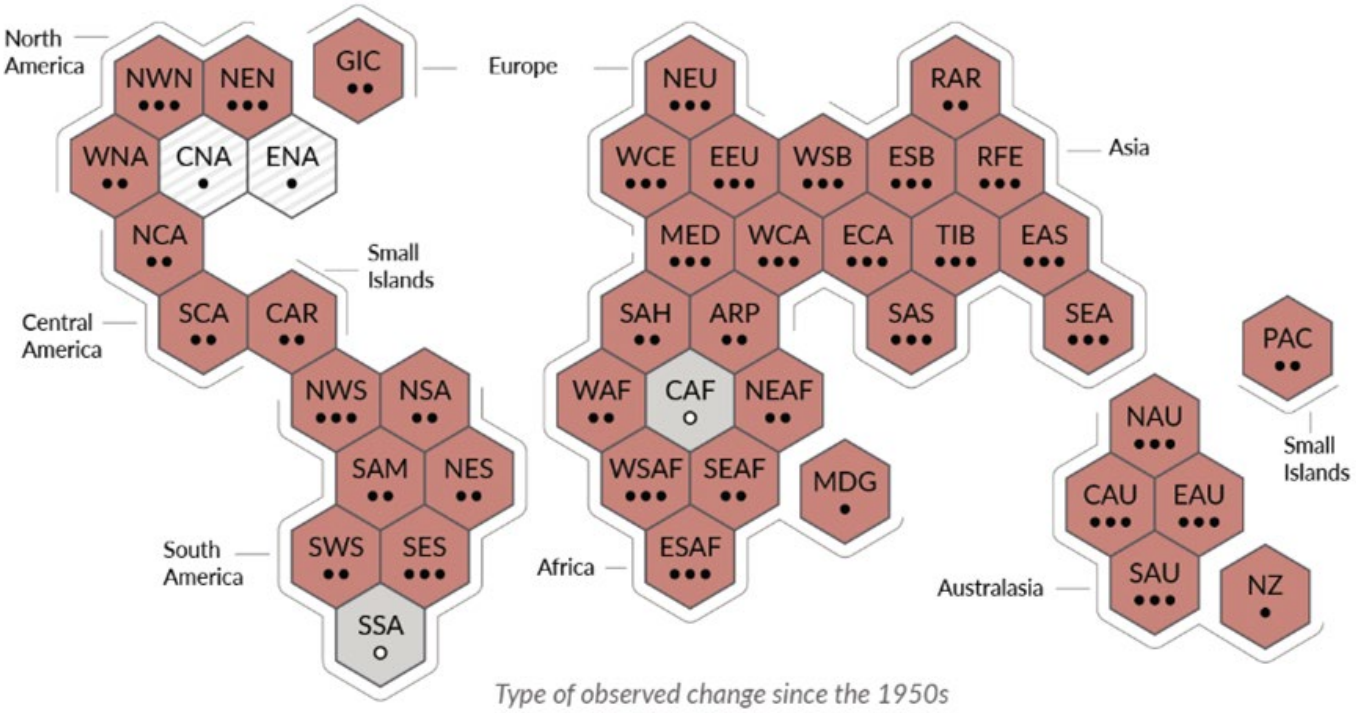


Warming occurred at a faster rate after the 1970s compared to the first half of the 21st century.

Cross-Section Box TS.1, Figure 1

Climate change is already affecting every region on Earth

Hot extremes



Type of observed change

Colour = Increase/decrease

Low agreement in the type of change

Limited data and/or literature

Confidence in human contribution to the observed change

●●● High

●● Medium

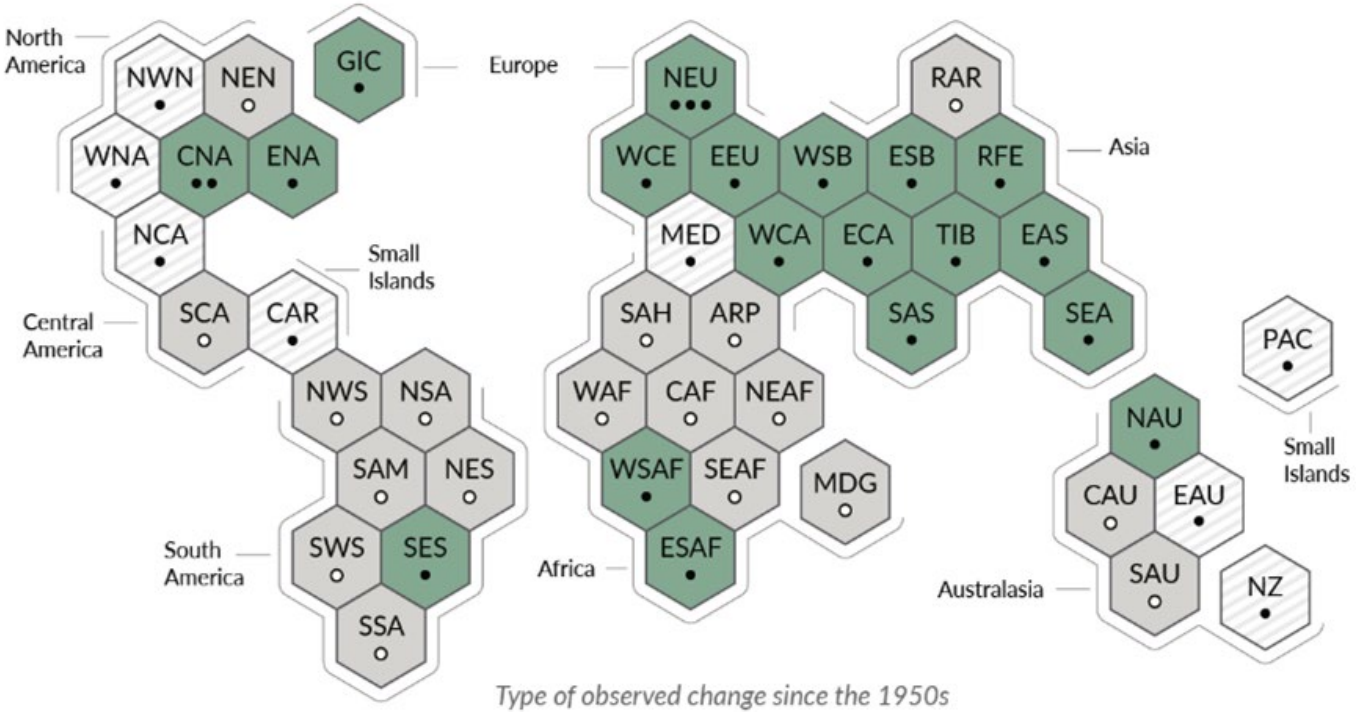
● Low due to limited agreement

○ Low due to limited evidence

Figure SPM.3

Climate change is already affecting every region on Earth

Heavy precipitation



Type of observed change

Colour = Increase/decrease

Low agreement in the type of change

Limited data and/or literature

Confidence in human contribution
to the observed change

●●● High

●● Medium

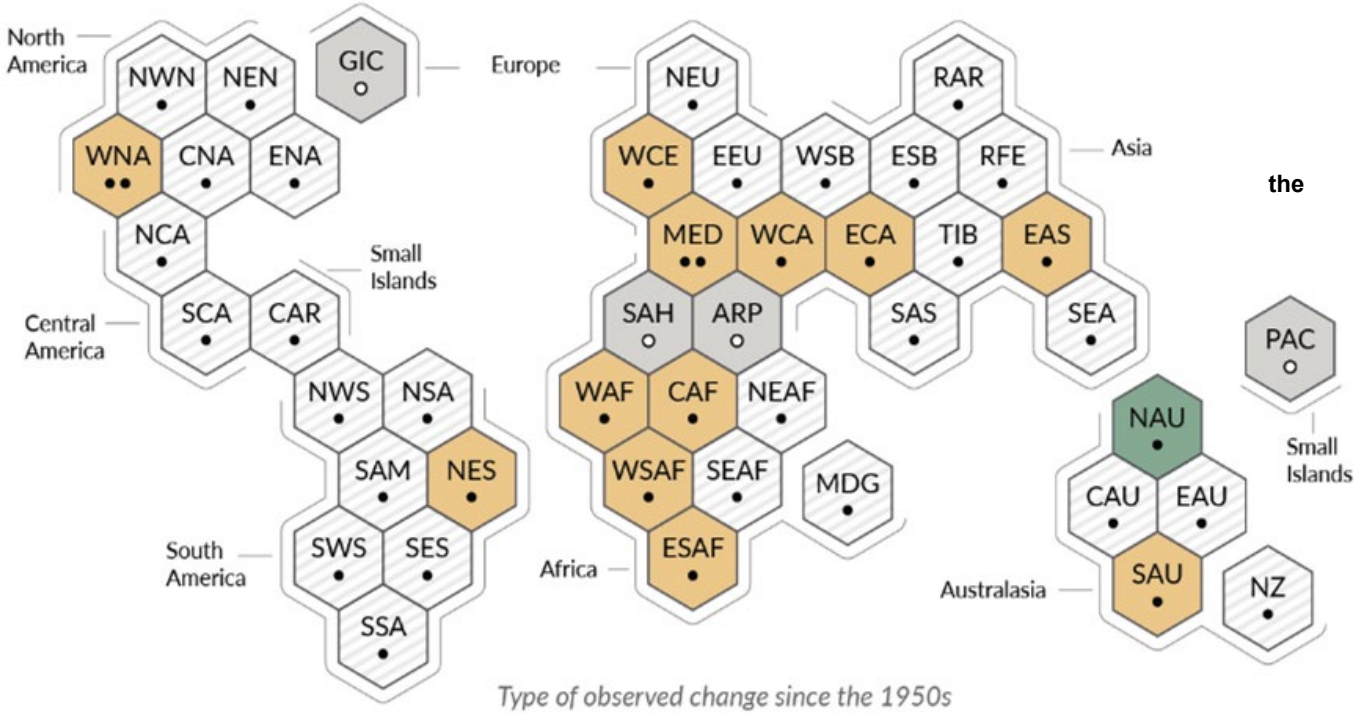
● Low due to limited agreement

○ Low due to limited evidence

Figure SPM.3

Climate change is already affecting every region on Earth

Agricultural and ecological drought



Type of observed change
Colour = Increase/decrease

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

Figure SPM.3

Section A - Current state of the climate

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- Climate change is already affecting every region on Earth, in multiple ways.
- Climate change is making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.

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B. Possible climate futures

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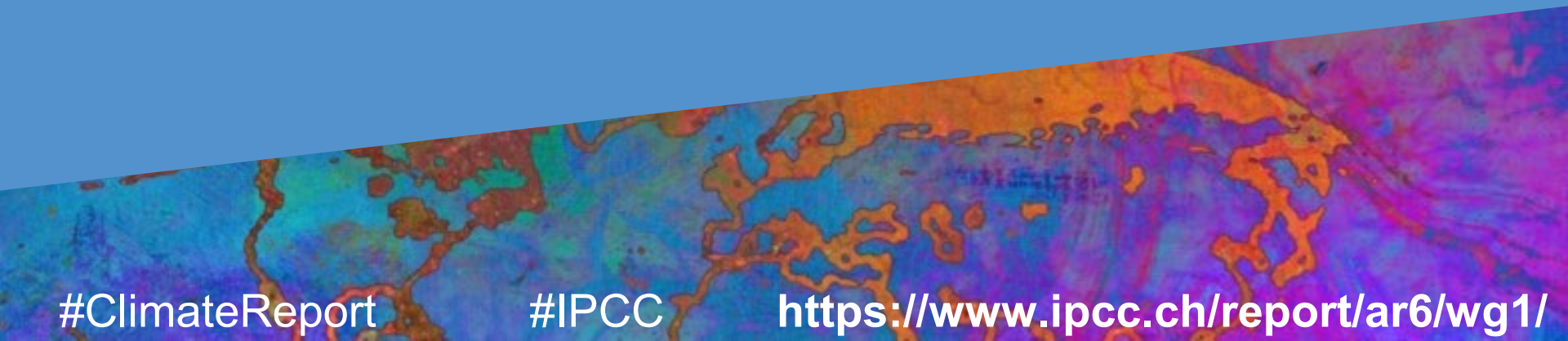
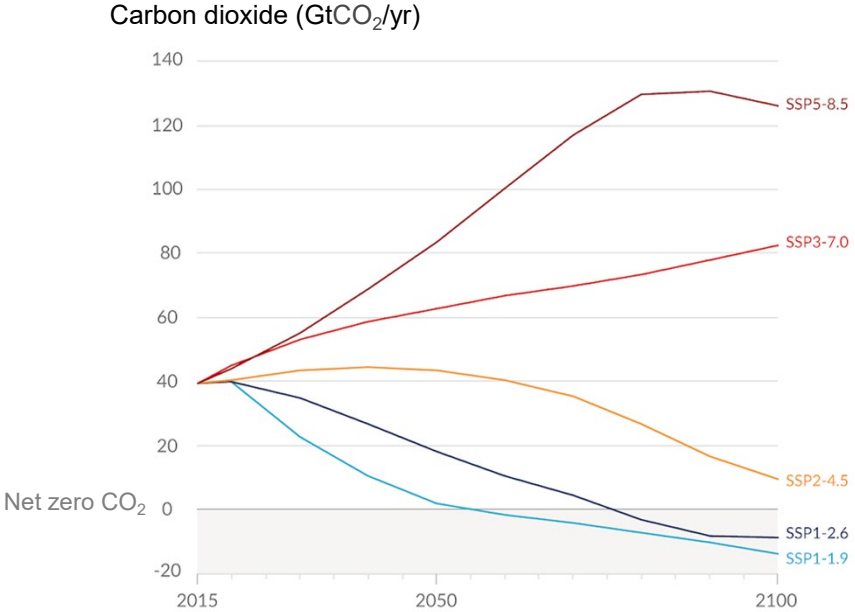


Section B - Possible climate futures

- Global surface temperature will continue to increase and global warming levels of 1.5°C and 2°C will be exceeded unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades
- Every increment of warming matters as many changes intensify in direct relationship with global warming
- Some changes are irreversible on centuries to millennia but can be slowed by limiting warming

The illustrative set of five SSP scenarios span a broader range of greenhouse gas and air pollutant futures than assessed in earlier WGI reports

Shared Socioeconomic Pathway (SSP) Scenarios



Very high

High

CO_2 emission pathways without any climate change mitigation

Intermediate

CO_2 emission pathway

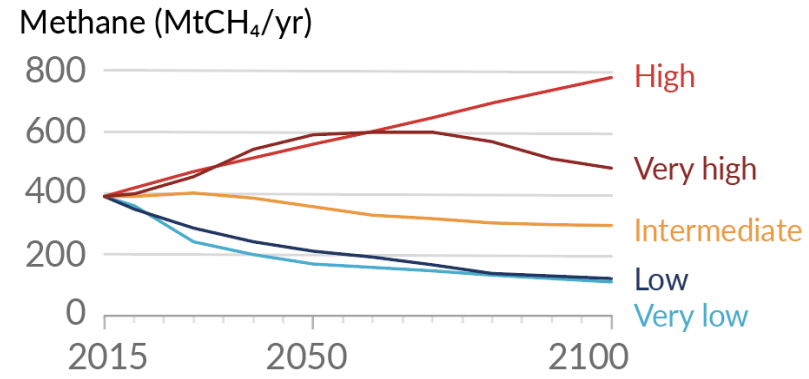
Low

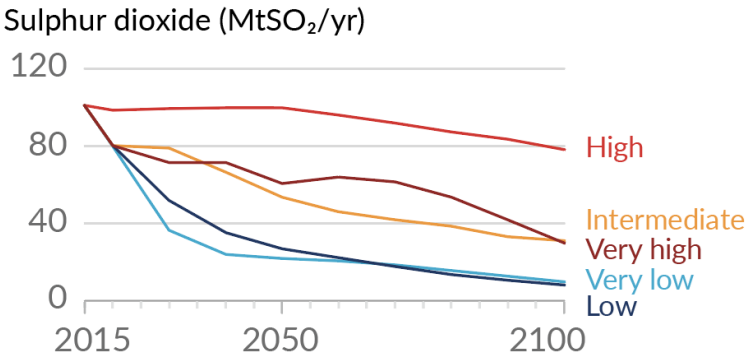
Very low

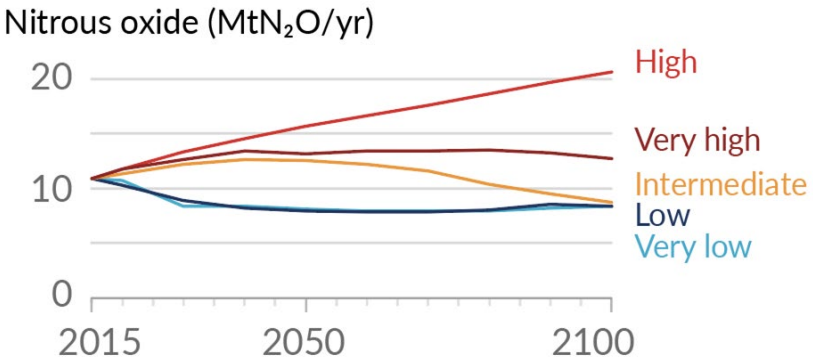
CO_2 emission pathways in which CO_2 emissions decline to net zero around or after 2050

Box SPM.1, Figure SPM.4

The illustrative set of five SSP scenarios span a broader range of greenhouse gas and air pollutant futures than assessed in earlier WGI reports







Box SPM.1, Figure SPM.4

Broad agreement across multiple lines of evidence, supporting a best estimate of equilibrium climate sensitivity of 3°C, with a *likely* range of 2.5°C to 4°C

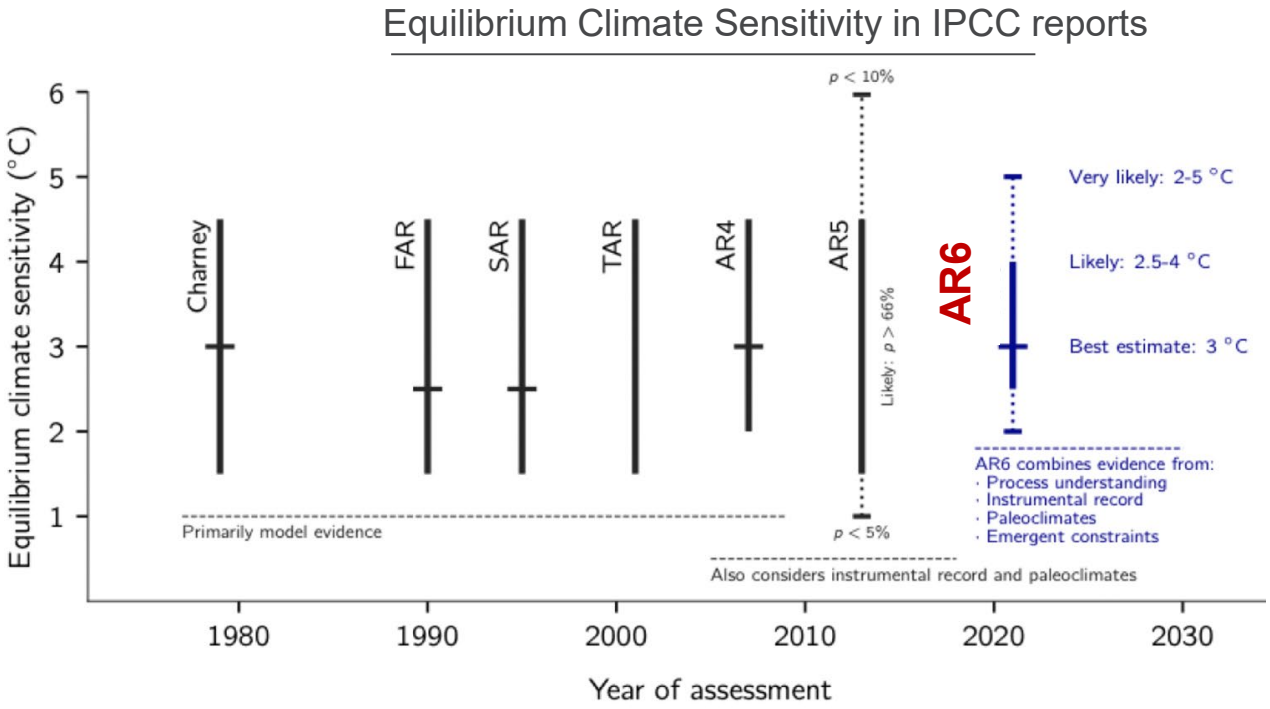


Figure TS.16

Global warming of 1.5°C and 2°C will be exceeded unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades

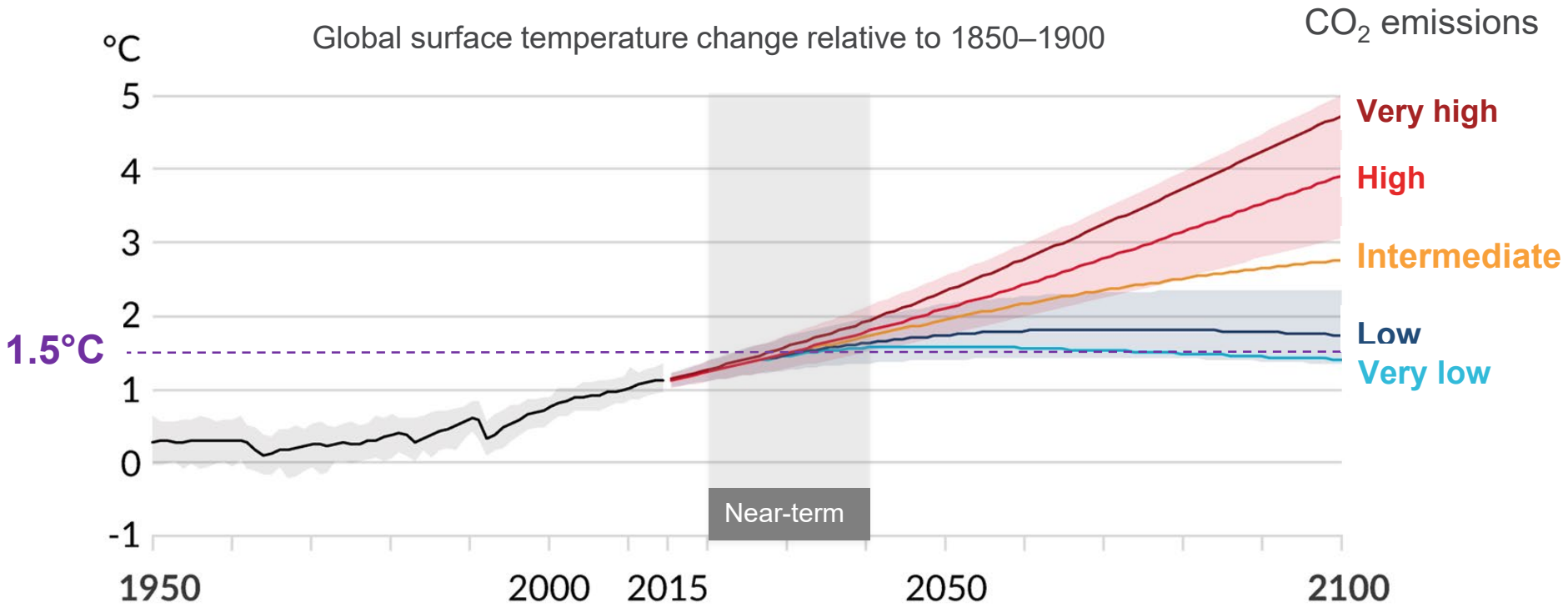


Figure SPM.8

Global warming of 1.5°C and 2°C will be exceeded unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades

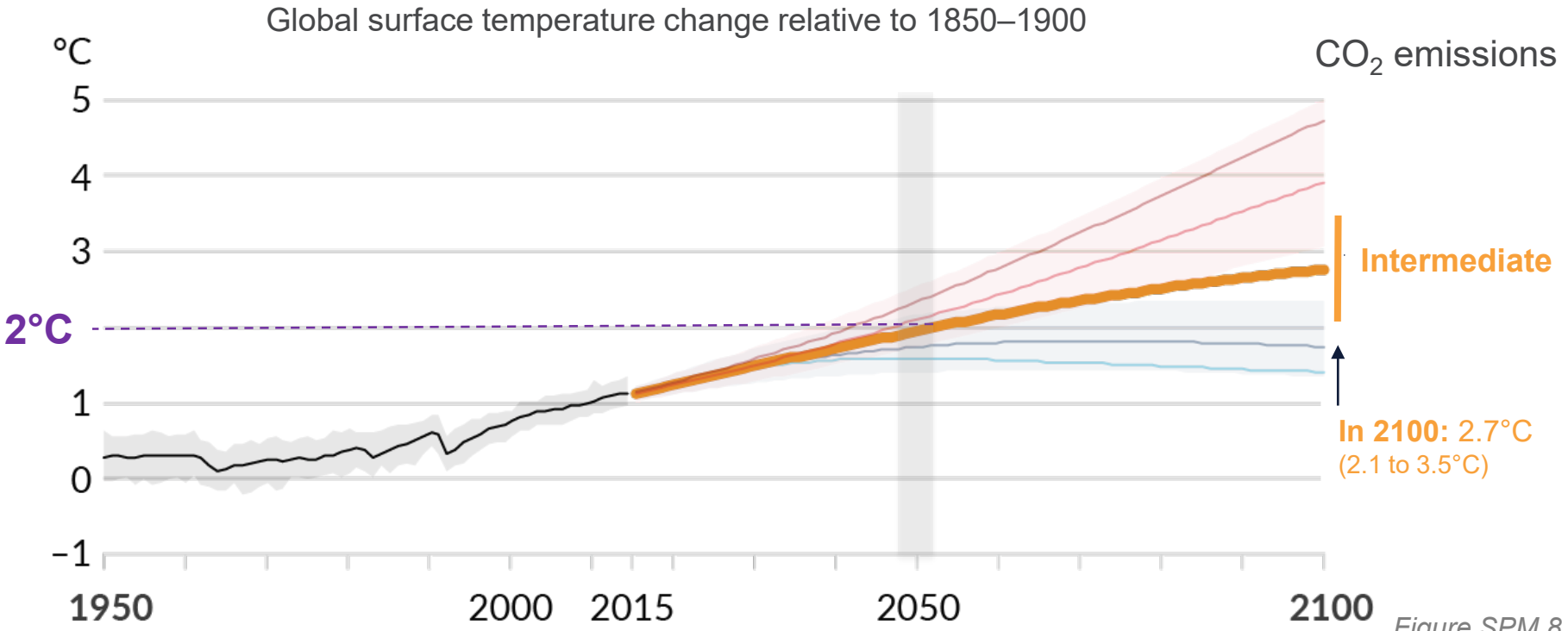


Figure SPM.8

Projections in the context of the Earth's climate history

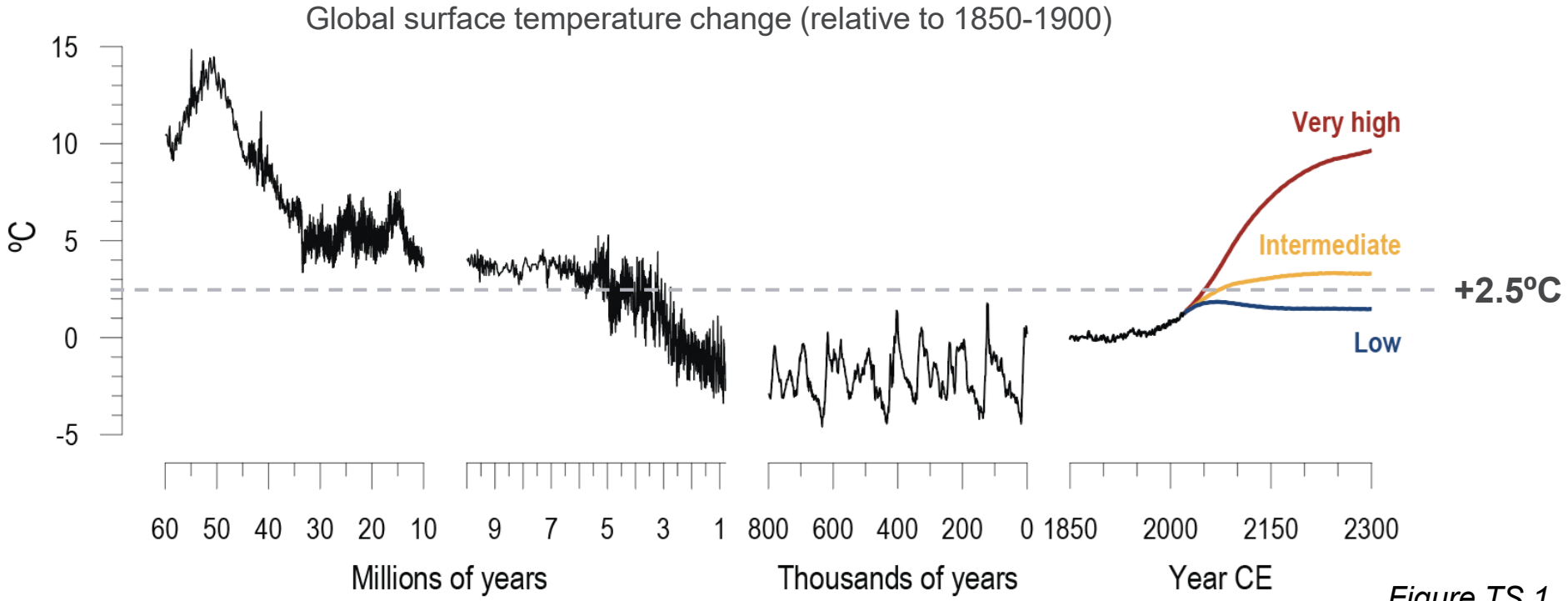
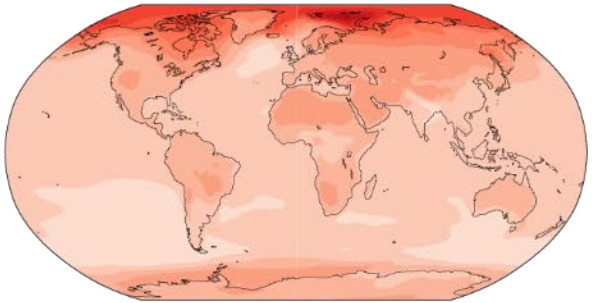


Figure TS.1

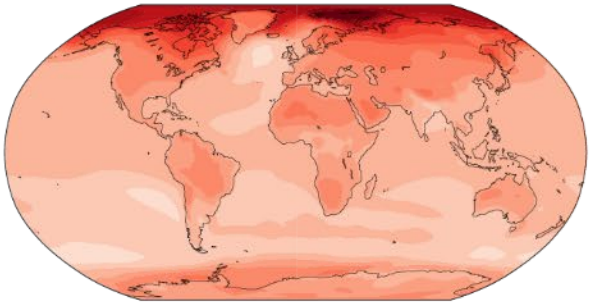
With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture

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

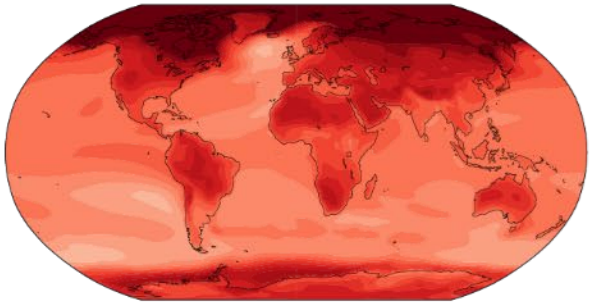
1.5°C



2°C



at 4°C



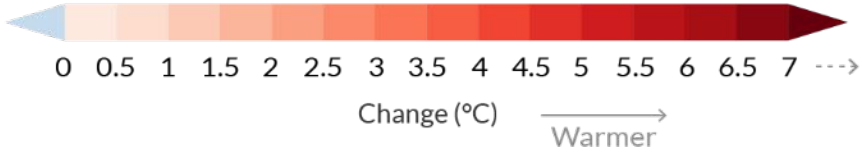


Figure SPM.5

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

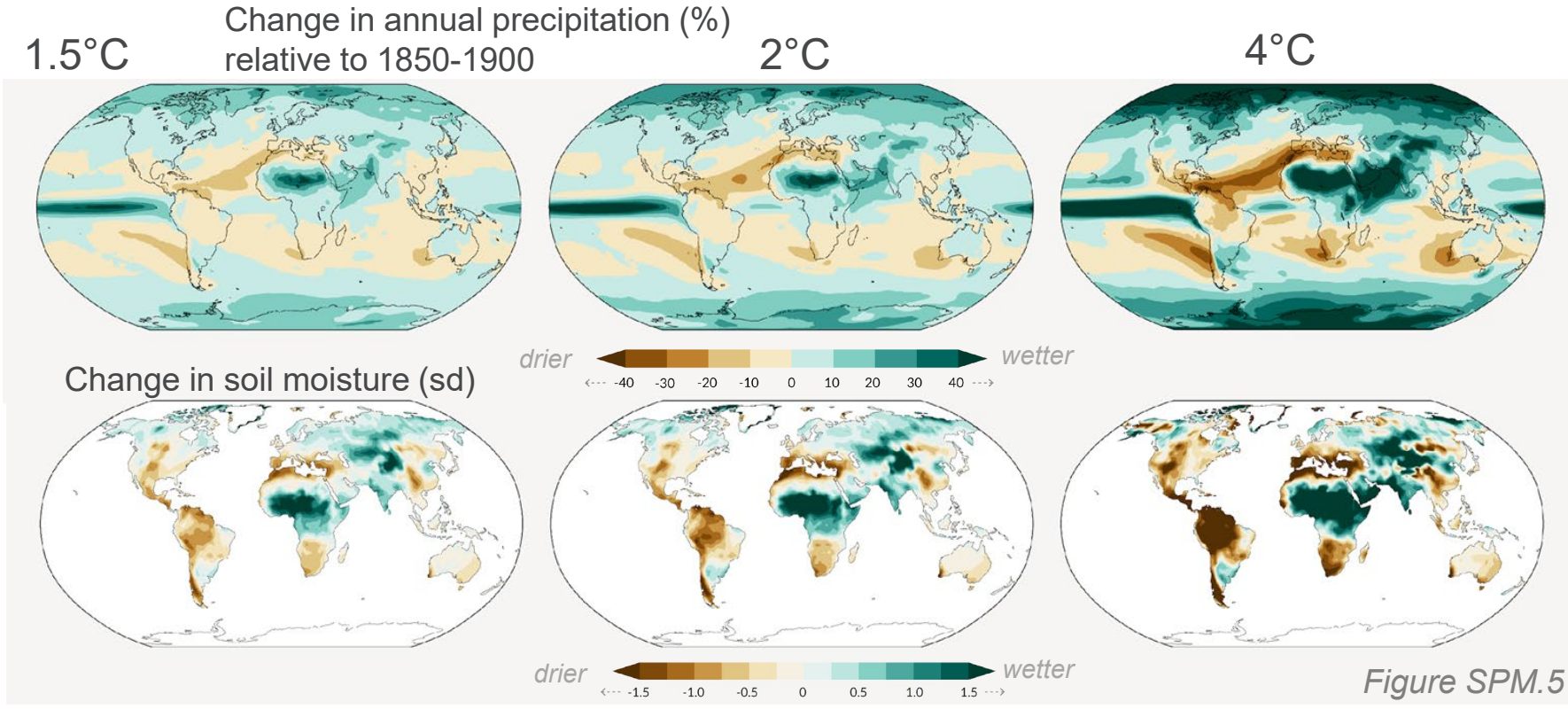
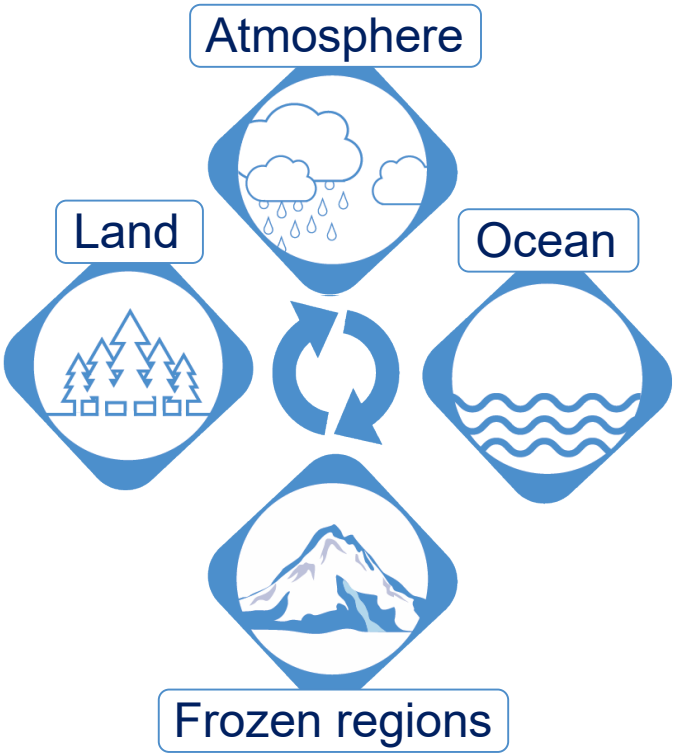


Figure SPM.5

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



Heatwaves, heavy precipitation and droughts are projected to be larger in frequency and intensity with every additional increment of global warming

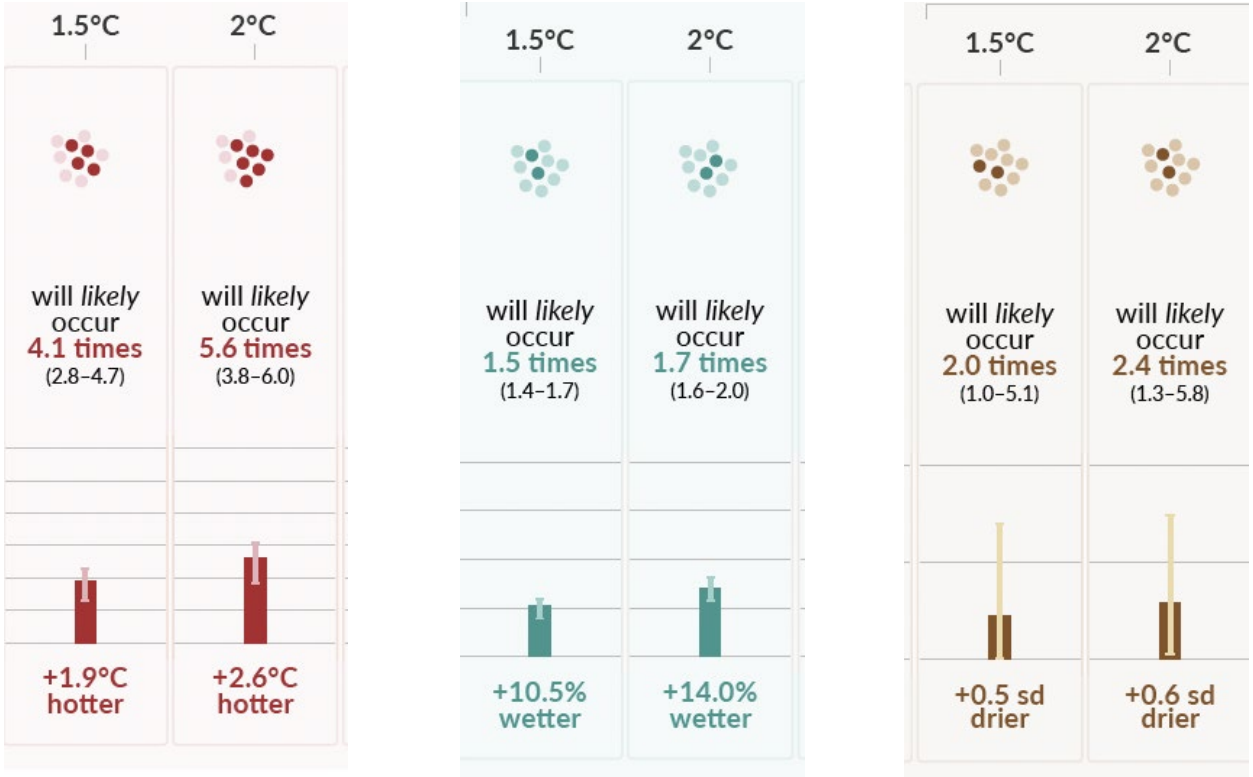


Figure SPM.6

Many changes in the climate system become larger in direct relation to increasing global warming

↑ frequency and intensity
- hot extremes and marine heatwaves
- heavy precipitation **(+7% per °C)**
- drought in some regions

↑ proportion of intense tropical cyclones

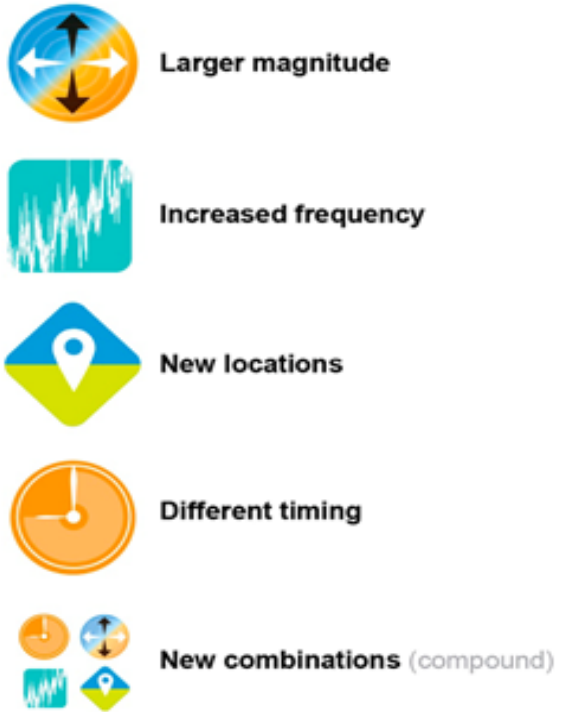


Figure FAQ11.2

Many changes in the climate system become larger in direct relation to increasing global warming

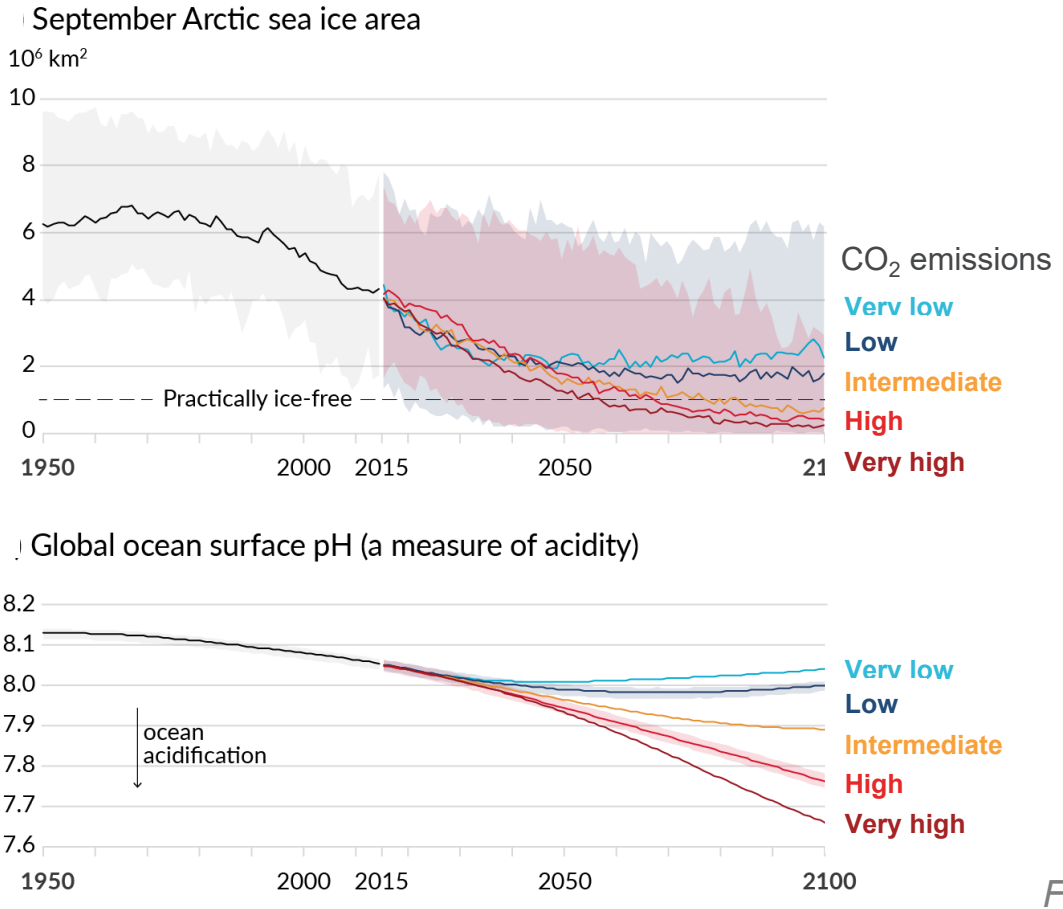


Figure SPM.8

Human activities affect all the major climate system components, with some responding over decades and others over centuries

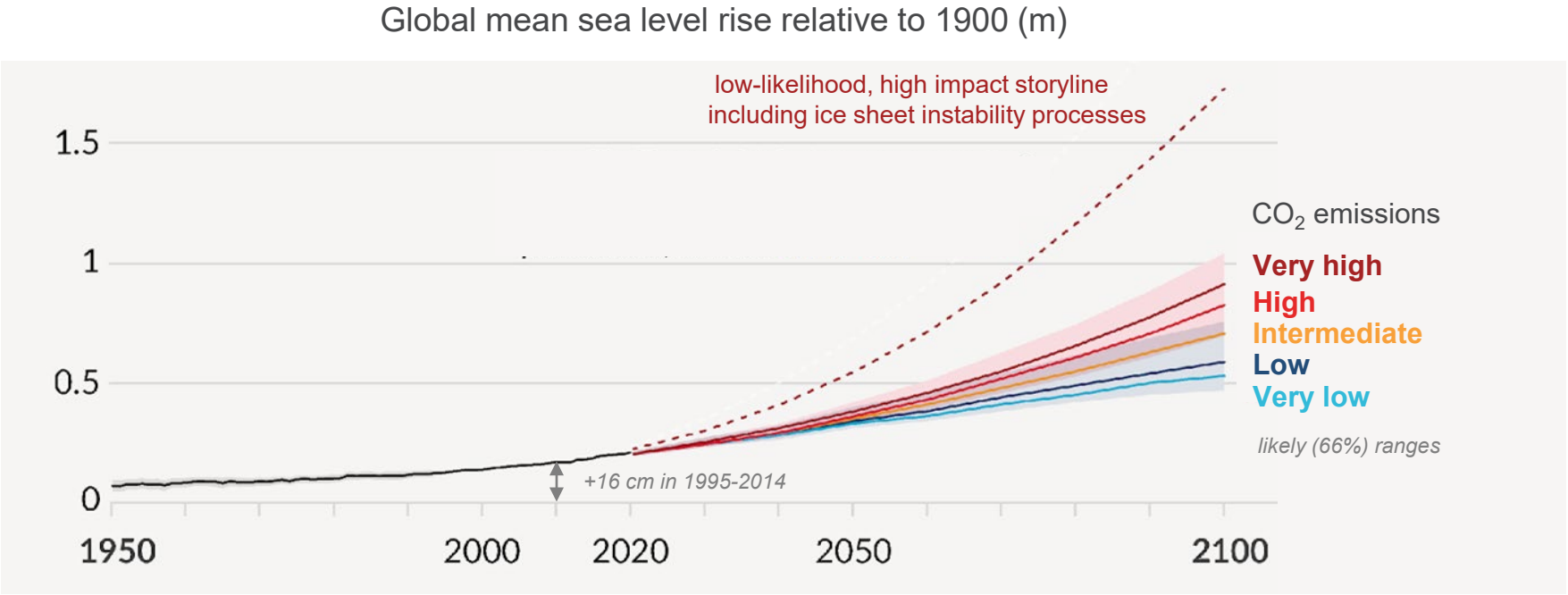


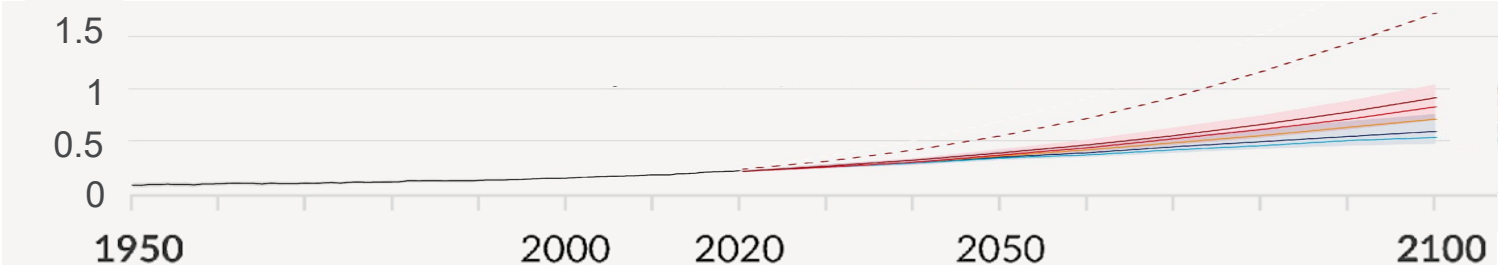
Figure SPM.8

Global mean sea level will continue to rise over thousands of years with a rate and magnitude depending on global greenhouse gas emissions

Sea level rise greater than 15 m cannot be ruled out with high emissions due to deep uncertainty on Antarctic ice sheet dynamics

Figure SPM.8

Global mean sea level rise relative to 1900 (m)



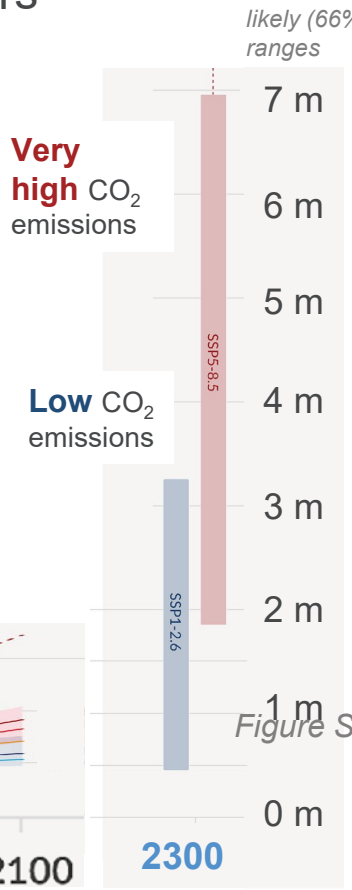
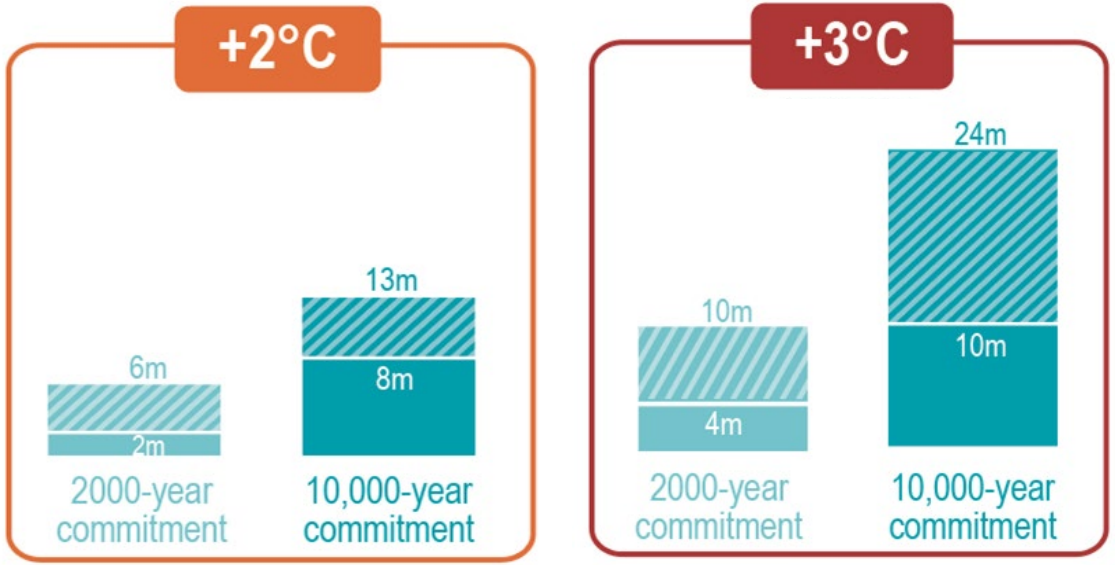


Figure SPM.8

Global mean sea level will continue to rise over thousands of years with a rate and magnitude depending on global greenhouse gas emissions

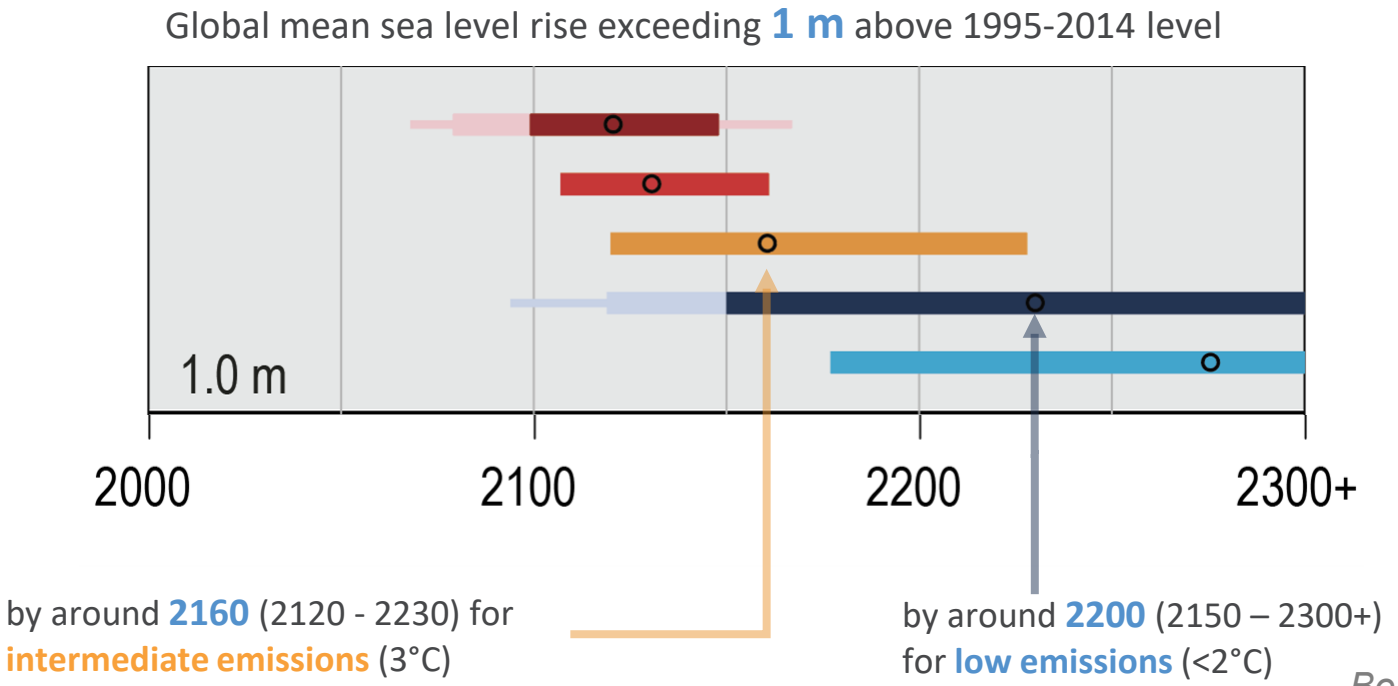
Global mean sea level rise relative to 1900 (m)



medium agreement, limited evidence

Infographic TS.1

Global mean sea level will continue to rise over thousands of years with a rate and magnitude depending on global greenhouse gas emissions



Box TS.4, Figure 1

Section B - Possible climate futures

- Global surface temperature will continue to increase and global warming levels of 1.5°C and 2°C will be exceeded unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades
- Every increment of warming matters as many changes intensify in direct relationship with global warming
- Some changes are irreversible on centuries to millennia but can be slowed by limiting warming

SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

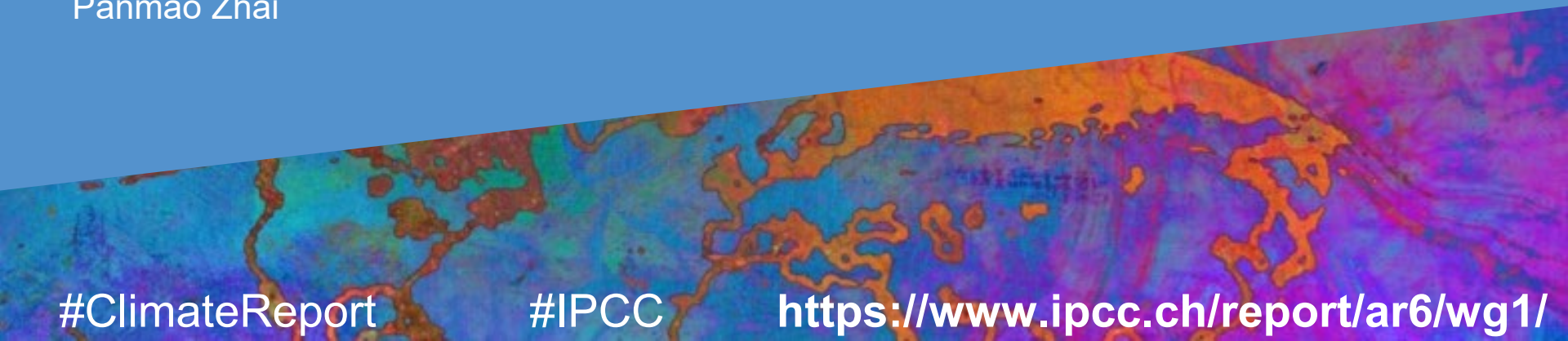
ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

SBSTA: 4 November 2021

C. Climate information for risk and adaptation

Valérie Masson-Delmotte
Panmao Zhai

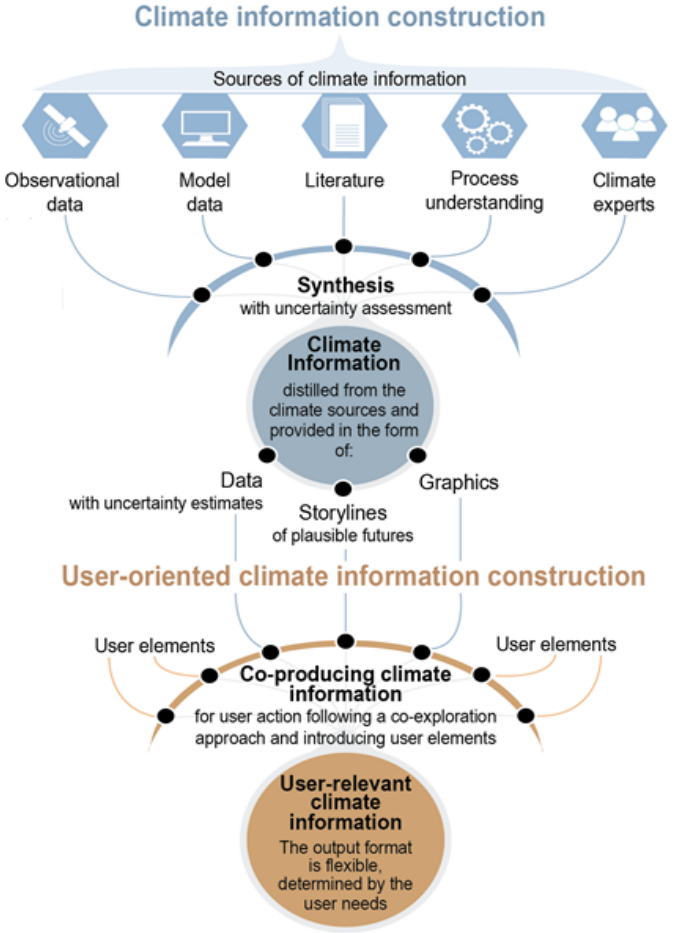


#ClimateReport #IPCC **https://www.ipcc.ch/report/ar6/wg1/**

Section C - Climate information for risk and adaptation

- Natural variability can amplify or obscure human-driven trends, especially at decadal and regional scales.
- Each region of the world will increasingly experience a specific combination of multiple changes.
- Some low-likelihood outcomes cannot be ruled out and these are important to understand for risk assessment. Their likelihood increases with global warming.
- Reducing greenhouse gas emissions would reduce the frequency, duration, and regions where heat extremes reach critical thresholds for health and agriculture.

Multiple lines of evidence are distilled for the co-production of user-relevant regional climate information framed by context and values



Chapter 10, Figure 10.1

Natural variability can enhance or reduce near term climate changes, particularly on regional scales

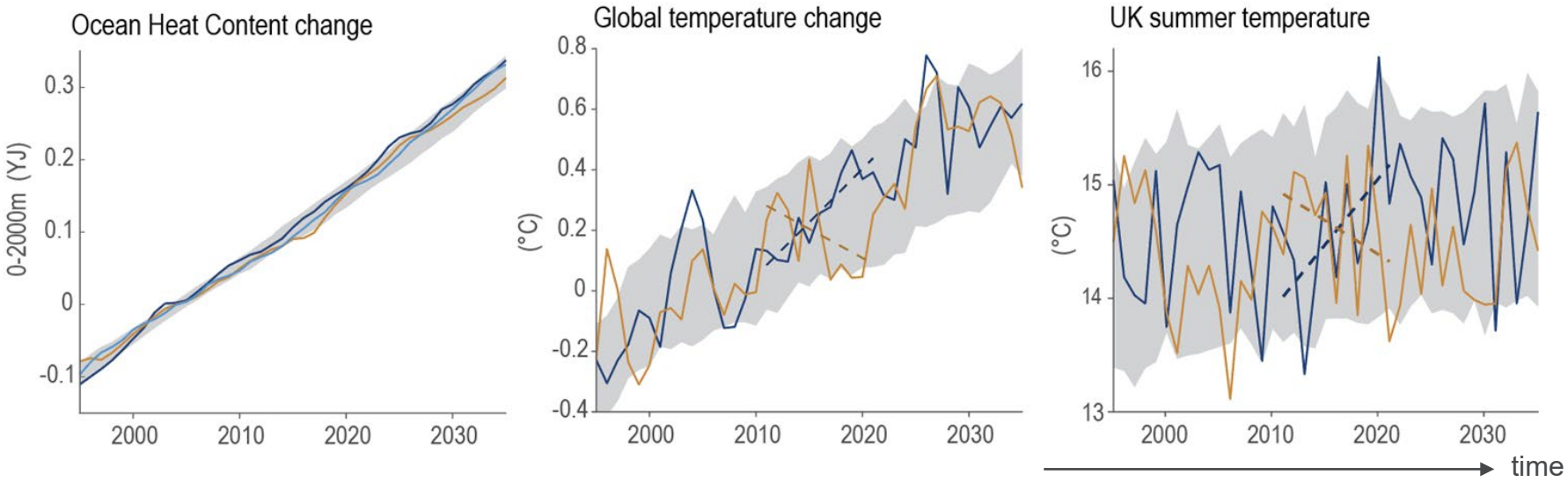
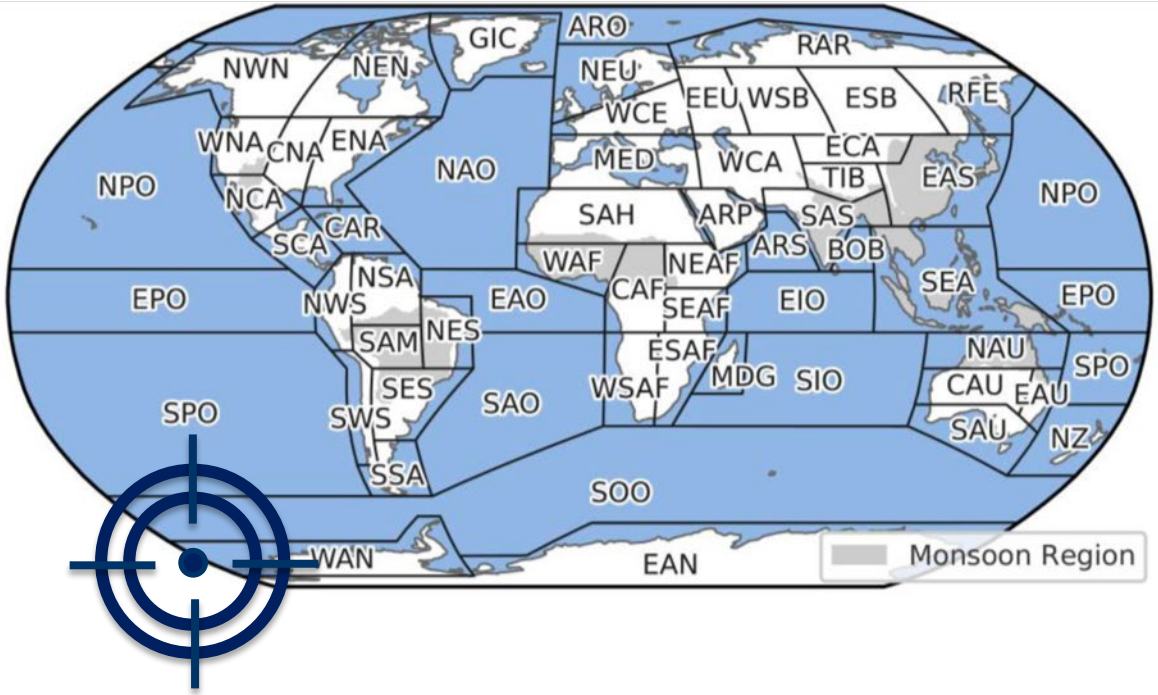
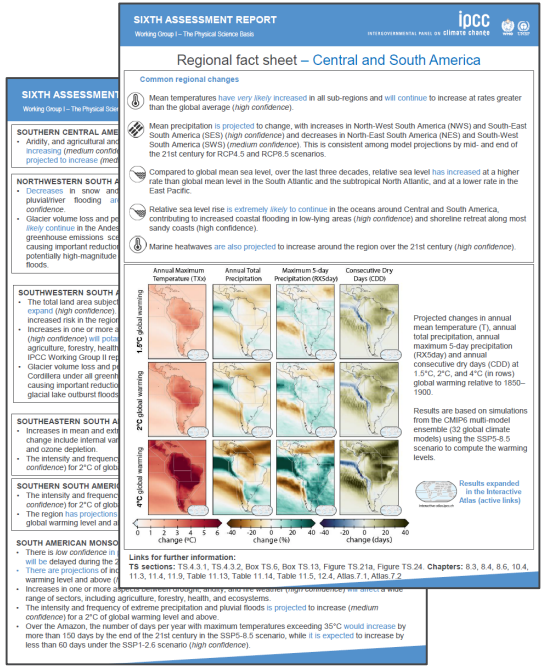


Figure 1.13

Regional climate assessment





Multiple climatic impact-drivers will change in all regions of the world

Heat & cold

Rain & drought

Snow & ice

Wind

Coastal & oceanic

Other

Open ocean

A **climatic impact-driver is a** physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems

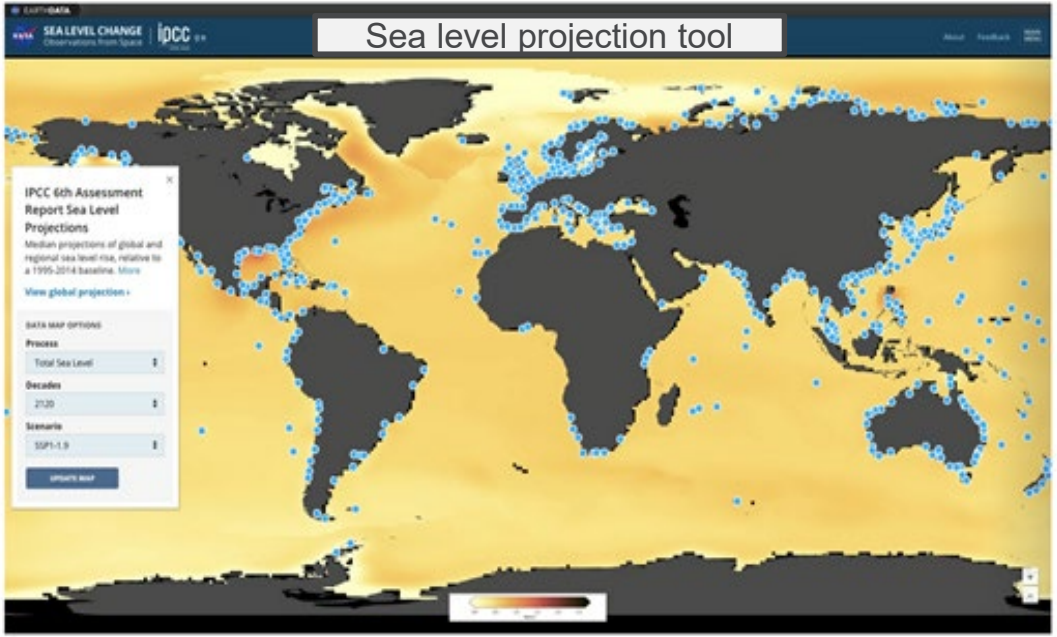
Worldwide changes in heat, cold, snow and ice, coastal, oceanic climatic impact-drivers will continue over the 21st century

Changes of CIDs related to the water cycle have a more region specific distribution

- All regions are projected to experience changes in at least 5 CIDs.
- 96% of regions are projected to experience changes in at least 10 CIDs.
- 50% of regions are projected to experience changes in at least 15 CIDs.

Regional sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts

Over the 21st century, the majority (2/3) of coastal locations have a median projected regional sea level rise within **± 20%** of the projected global mean sea level change



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

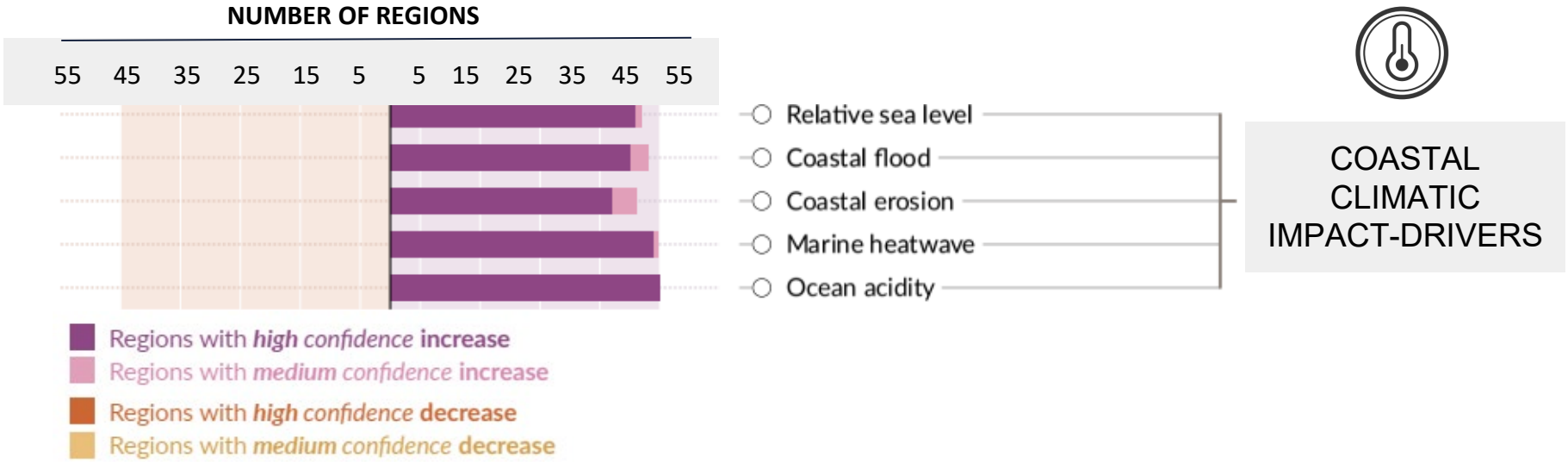
Regional sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts

Extreme sea levels that occurred once per century in the recent past will occur

- by 2050: 20 to 30 times more frequently
  annually or more frequently at about 19–31% of tide gauges

- by 2100 : at least 160 times more frequently,
  annually or more frequently at 60% (<2°C) to 80% (4°C) of tide gauges

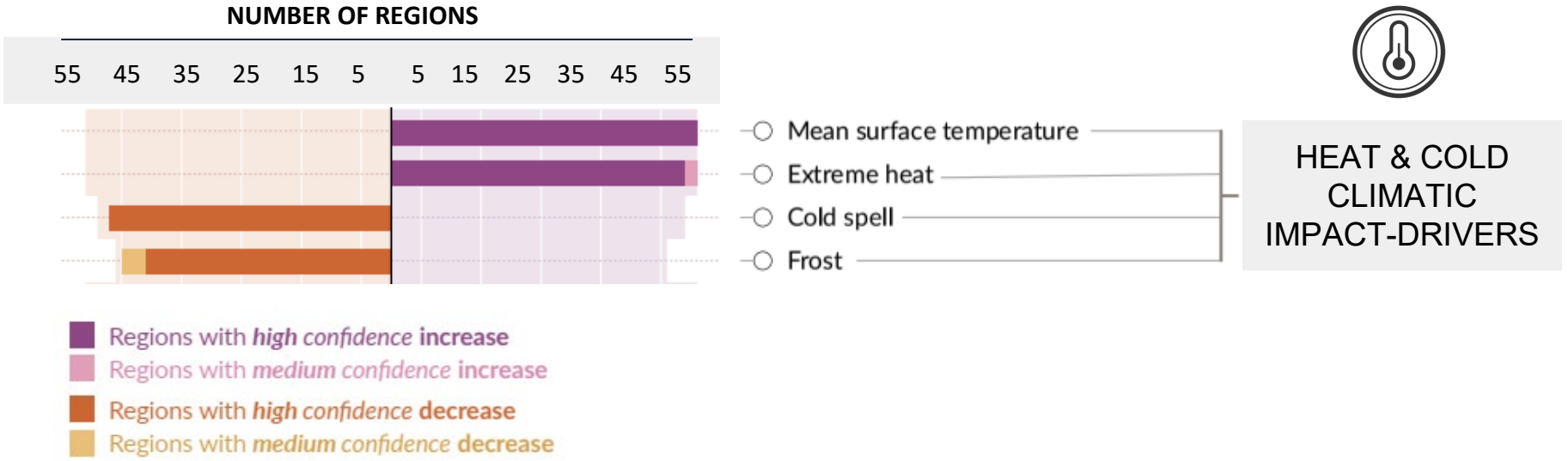
Regional sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts



by 2050 compared to 1960-2014 (2°C global warming)

Figure SPM.9

All regions are projected to experience further increases in hot climatic impact-drivers and decreases in cold CIDs



by 2050 compared to 1960-2014 (2°C global warming)

Figure SPM.9

At 2°C global warming and above, the magnitude of changes increases for droughts, heavy precipitation and associated flooding events, and for mean precipitation compared to those at 1.5°C

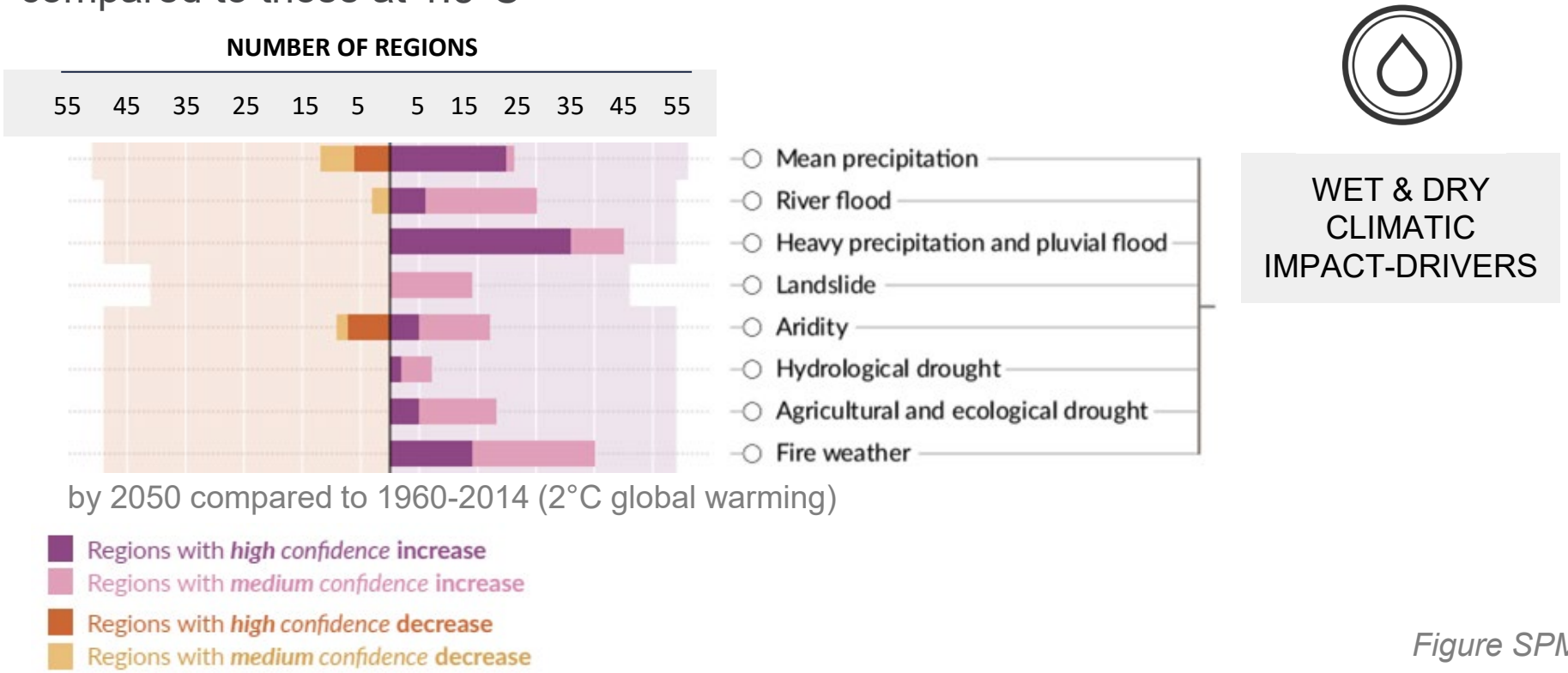
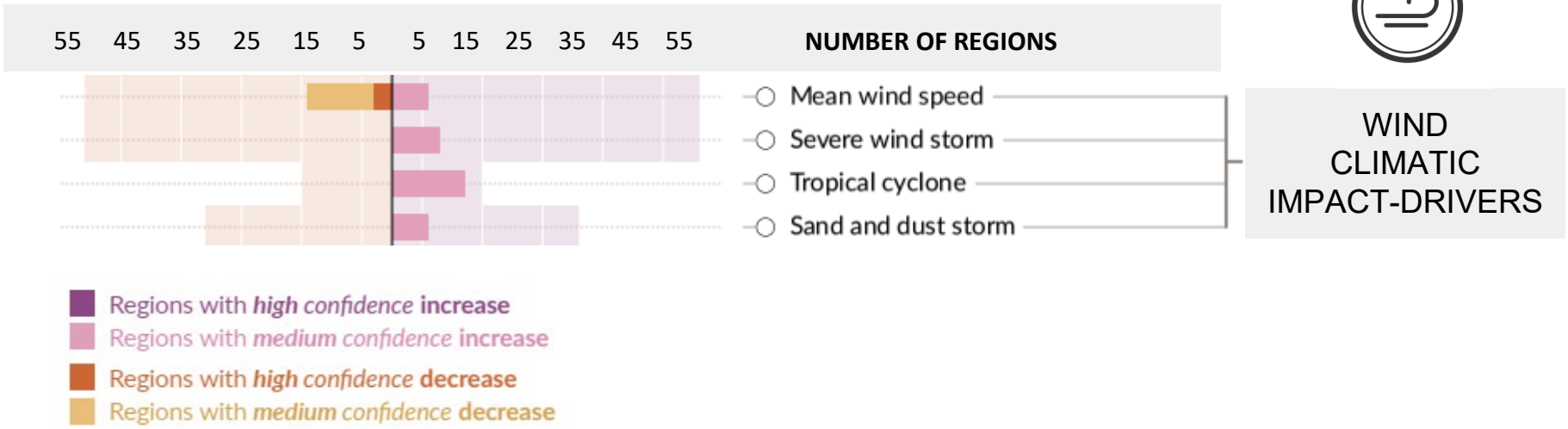


Figure SPM.9

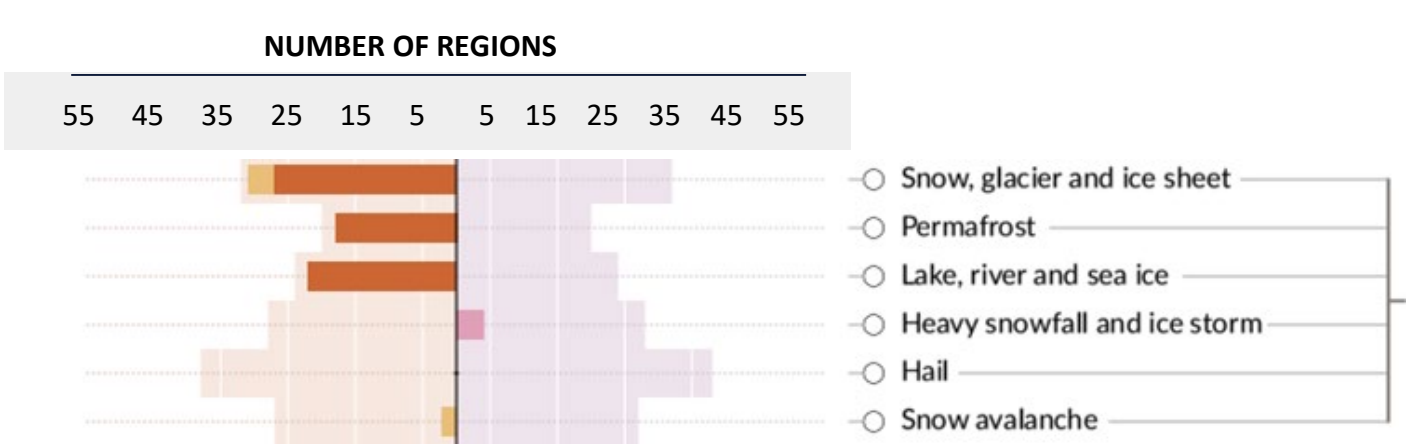
Region-specific changes include intensification of tropical cyclones and/or extratropical storms



by 2050 compared to 1960-2014 (2°C global warming)

Figure SPM.9

Widespread loss of snow and ice and permafrost thaw is projected in all concerned regions at global warming of 2°C.

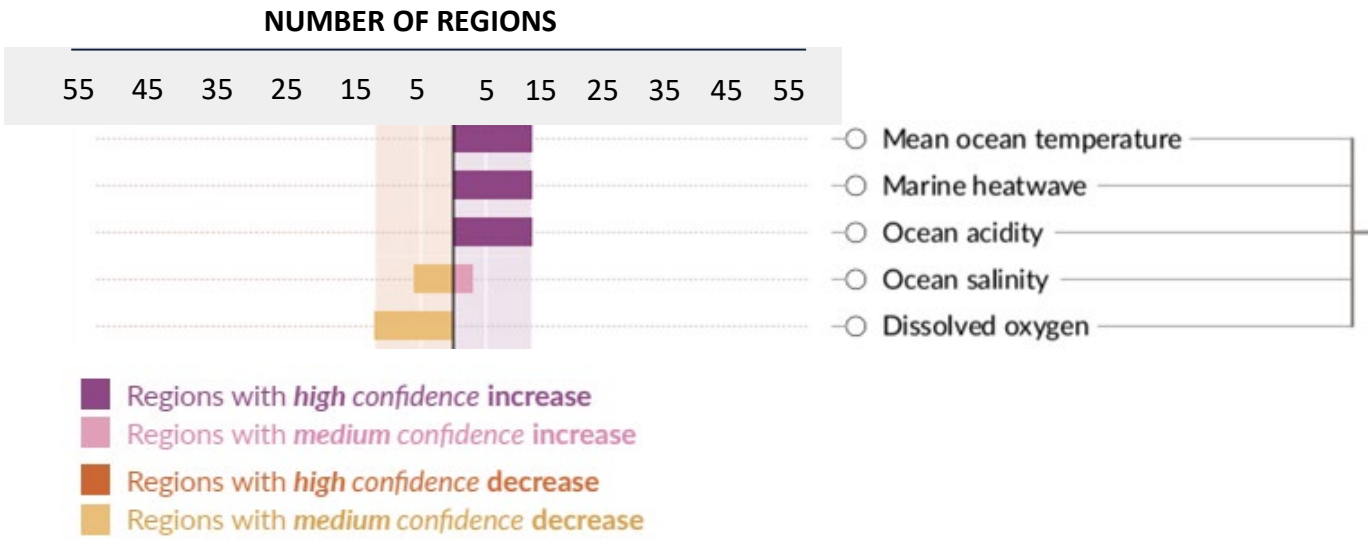


SNOW & ICE
CLIMATIC
IMPACT-DRIVERS

by 2050 compared to 1960-2014 (2°C global warming)

Figure SPM.9

The open ocean regions are projected to experience widespread warming, increased marine heatwaves, loss of oxygen and increased surface salinity contrasts due to the intensified water cycle



OPEN OCEAN CLIMATIC IMPACT-DRIVERS

by 2050 compared to 1960-2014 (2°C global warming)

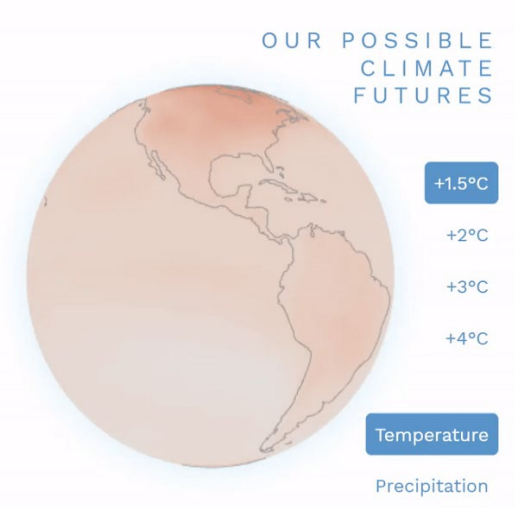
Figure SPM.9

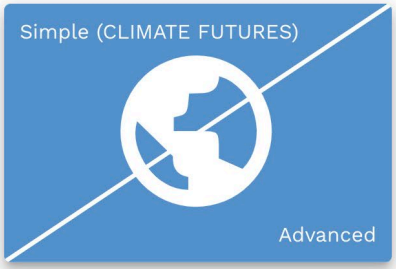
IPCC WGI Interactive Atlas

A novel tool for flexible spatial and temporal analyses of much of the observed and projected climate change information underpinning the Working Group I contribution to the Sixth Assessment Report, including regional synthesis for Climatic Impact-Drivers (CIDs).

Participate in the user testing survey

Errata and problem reporting



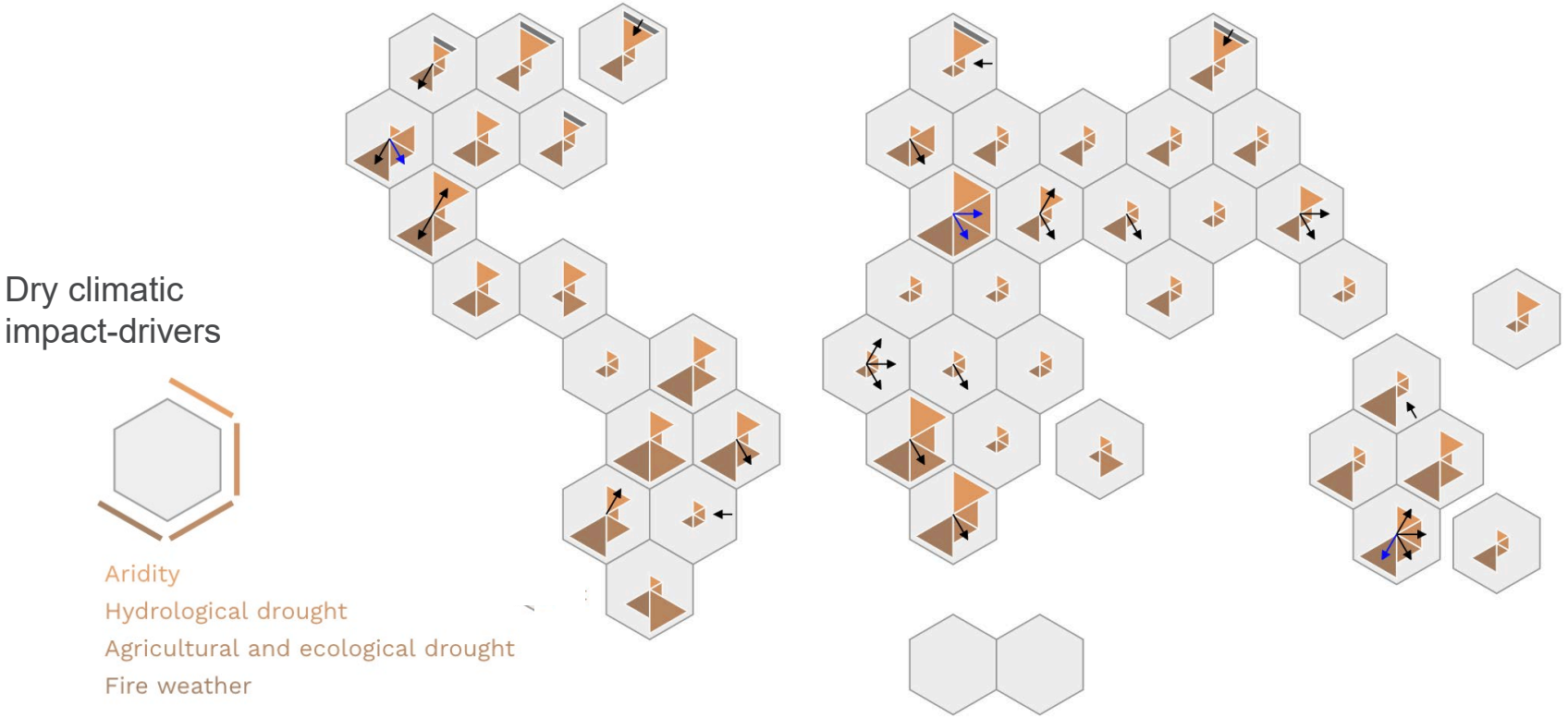


REGIONAL INFORMATION

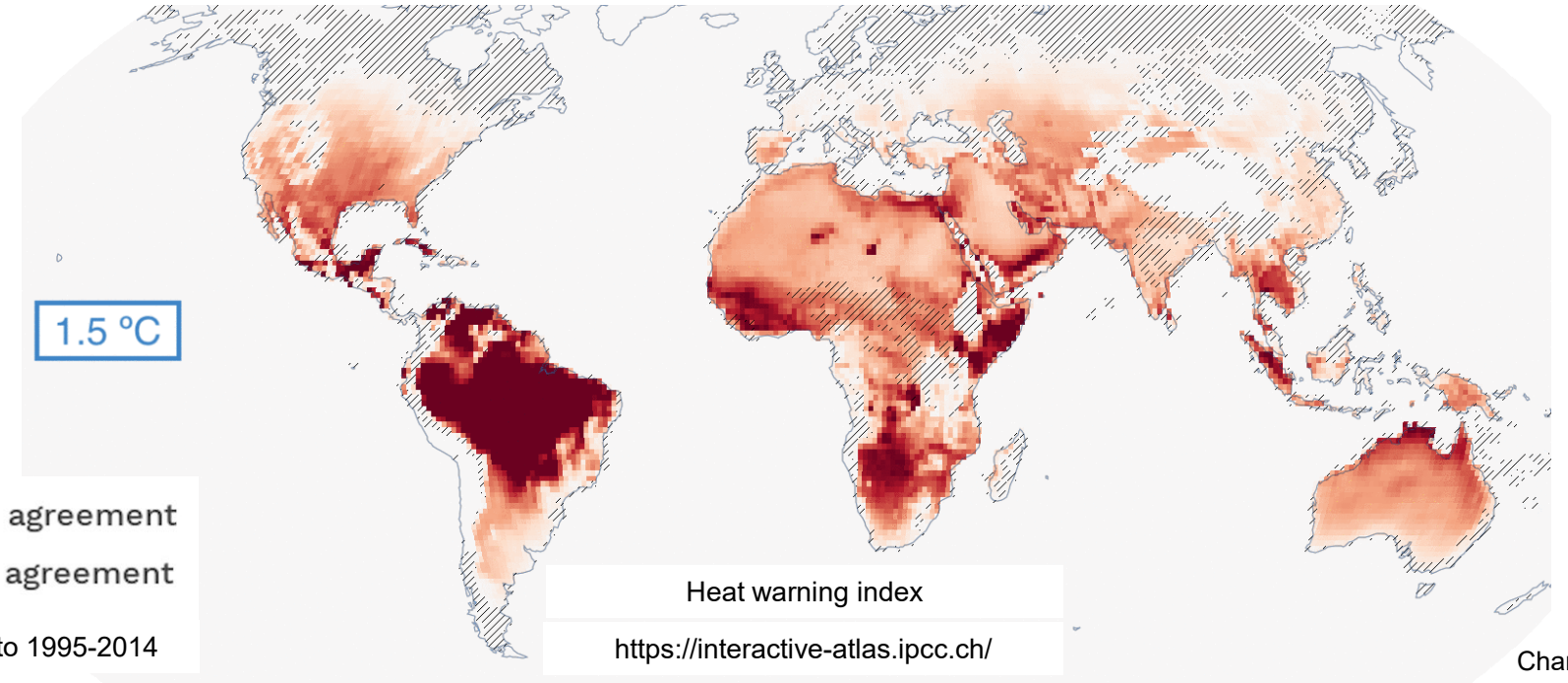
REGIONAL SYNTHESIS

DOCUMENTATION

Example of regional synthesis in the Interactive Atlas



Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels



Low Likelihood High Impact events

- The probability of occurrence is low but potential impacts on society and ecosystems could be high
- Their chance of occurrence increases with higher global warming
- They can occur at the global and regional scale

See Table 4.10

Section C - Climate information for risk and adaptation

- Natural variability can amplify or obscure human-driven trends, especially at decadal and regional scales.
- Each region of the world will increasingly experience a specific combination of multiple changes.
- Some low-likelihood outcomes cannot be ruled out and these are important to understand for risk assessment. Their likelihood increases with global warming.
- Reducing greenhouse gas emissions would reduce the frequency, duration, and regions where heat extremes reach critical thresholds for health and agriculture.

SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

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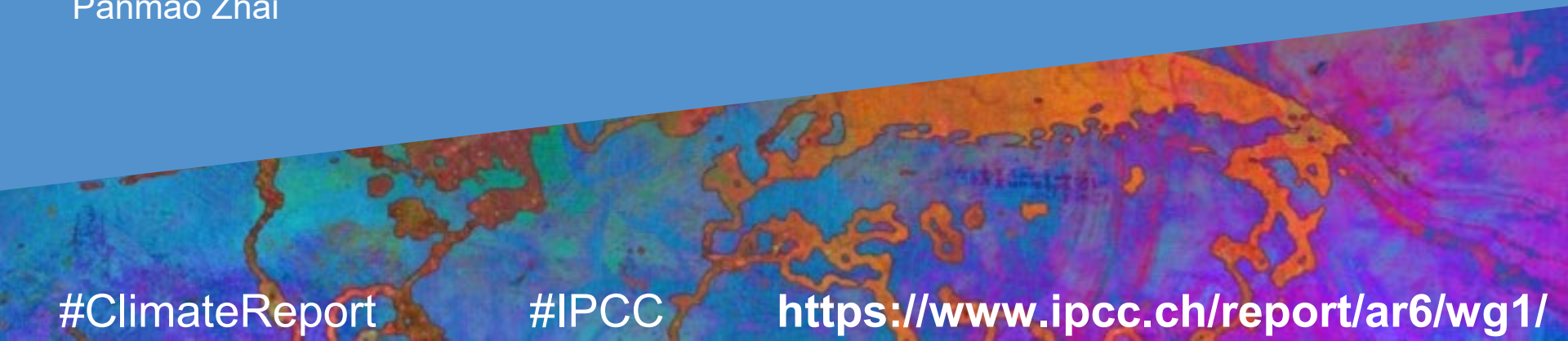
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

SBSTA: 4 November 2021

D. Limiting Climate Change

Valérie Masson-Delmotte
Panmao Zhai



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Section D - Limiting climate change

- Limiting global warming requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 and strong reductions in other greenhouse gas emissions
- Strong, rapid and sustained reductions in methane emissions would limit the warming effect from declining aerosol pollution and improve air quality
- Effects of strong emission reductions emerge within years for air quality and around 20 years for global surface temperature trends
- The climate we experience in the future depends on our decisions now.

Every tonne of CO_2 emissions adds to global warming

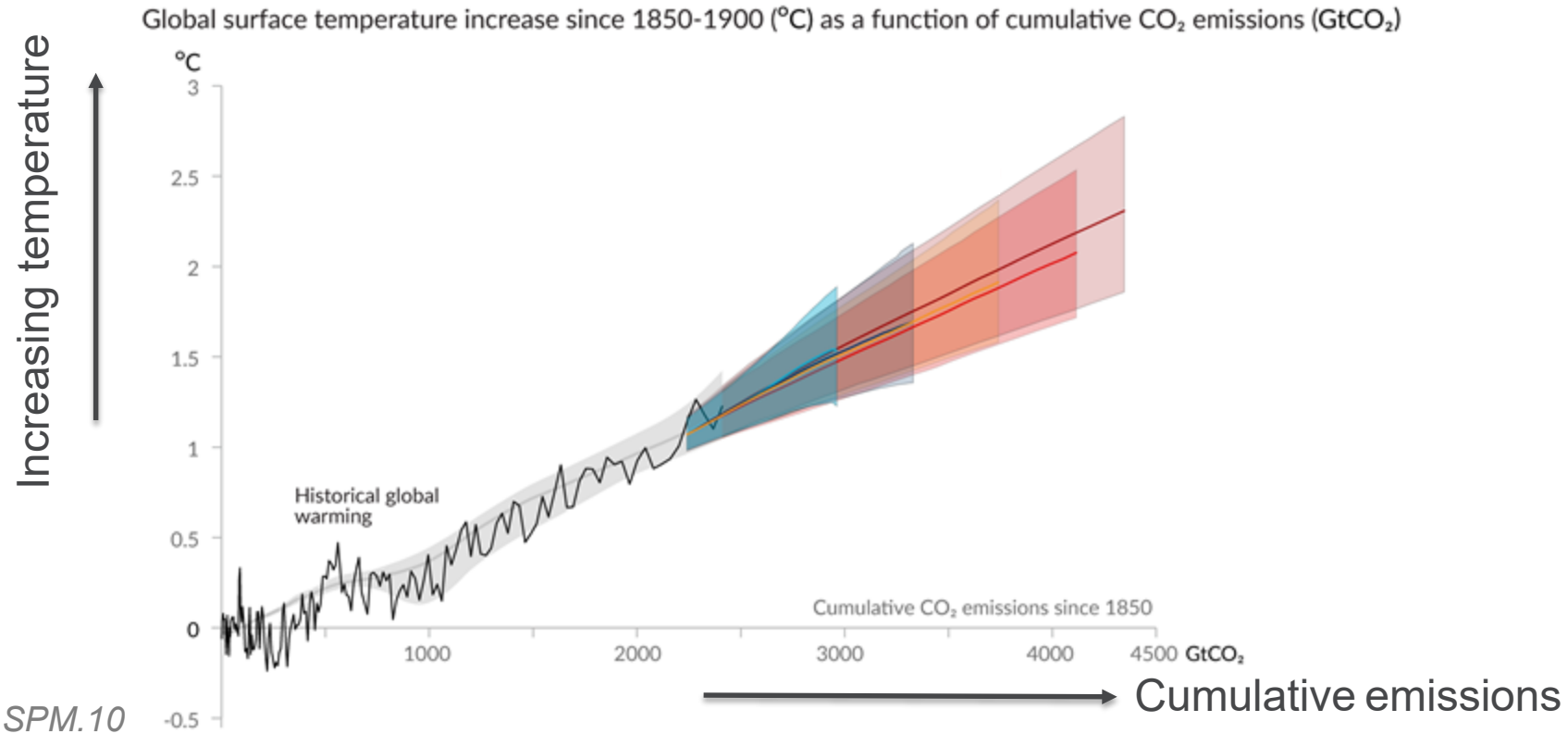
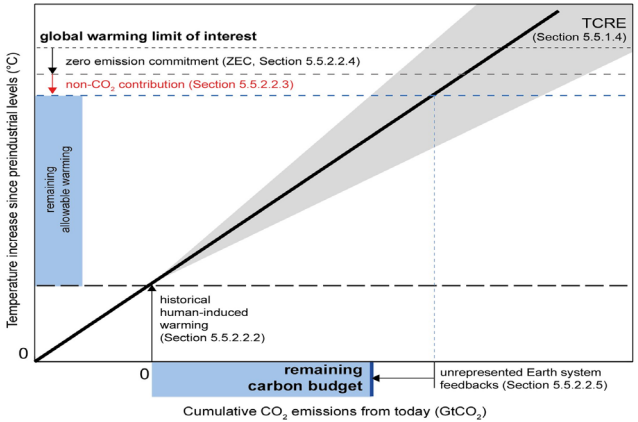


Figure SPM.10

An updated assessment of the total and remaining carbon budget



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)*(1)	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*(2)*					Variations in reductions in non-CO_2 emissions*(3)
		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	

Contributions of updated terms compensate leading to remaining budgets similar to SR1.5

- Emissions to date: 2390 $GtCO_2$ over 1850-2019 period
- Human-induced historical warming
- Warming per tonne CO_2 emitted
- Warming evolution after CO_2 emissions reach net zero
- Future warming from non- CO_2 emissions
- Earth system feedback otherwise not captured

Table SPM.2, Figure TS.14

Total cumulative CO_2 emissions taken up by land and ocean increases with the CO_2 emitted in the atmosphere but the fraction decreases

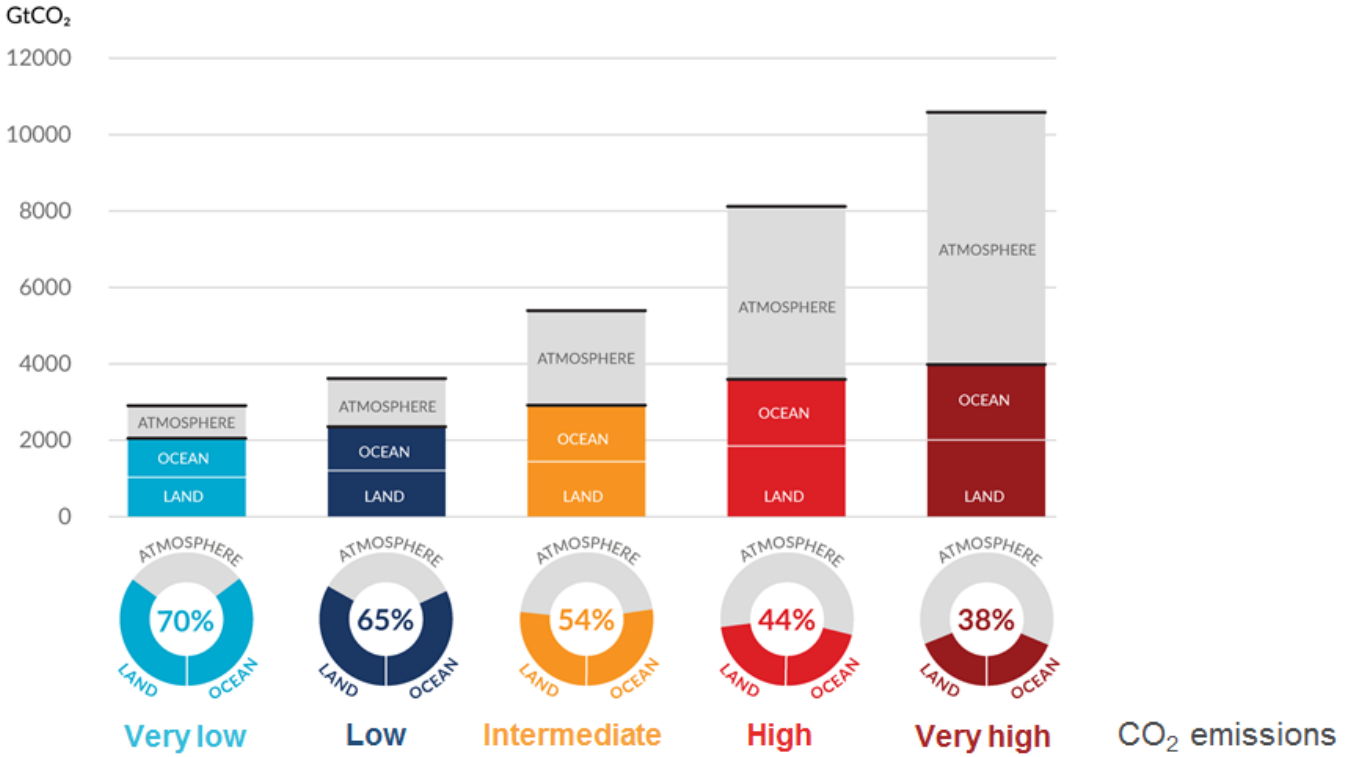
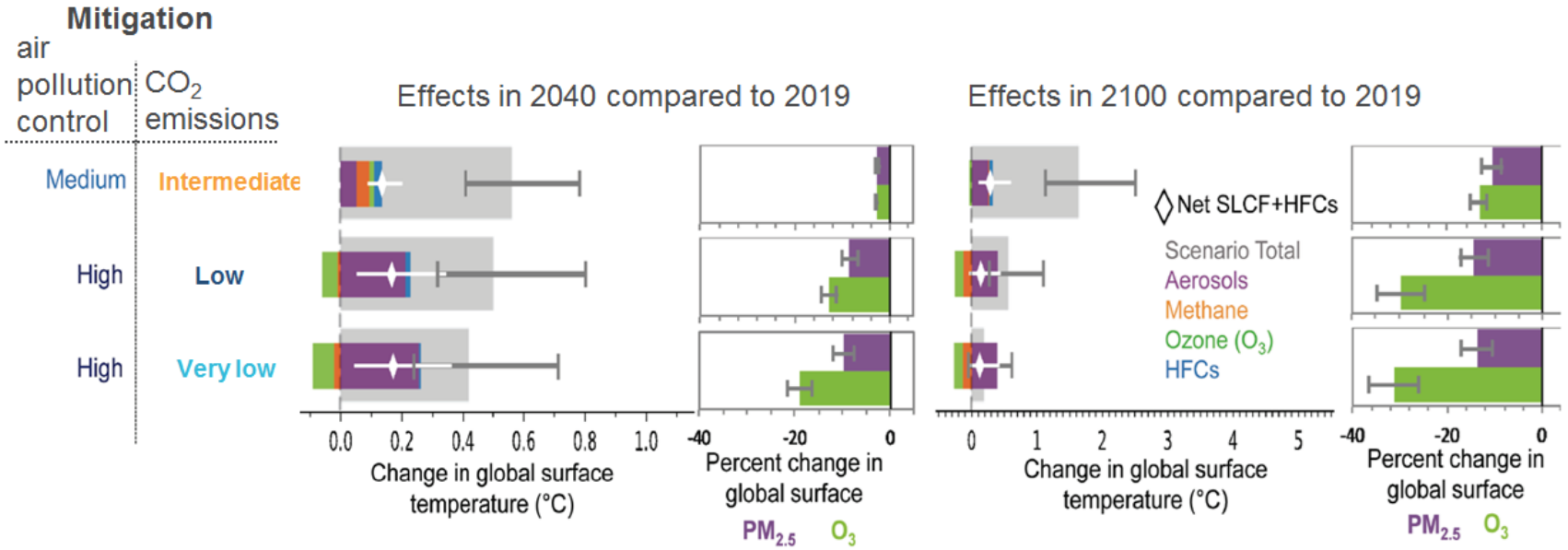


Figure SPM.7

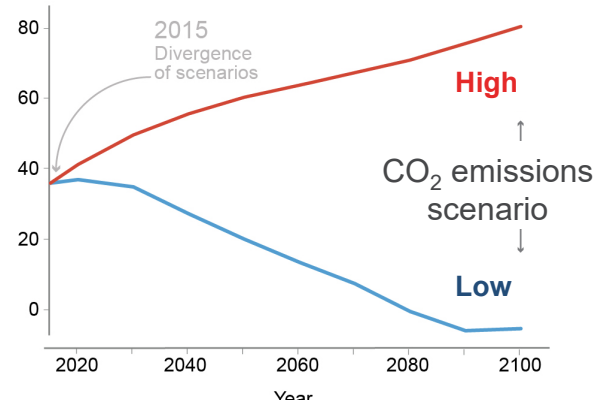
Strong, rapid and sustained reductions in CH4 emissions would limit the warming effect resulting from declining aerosol pollution and improve air quality



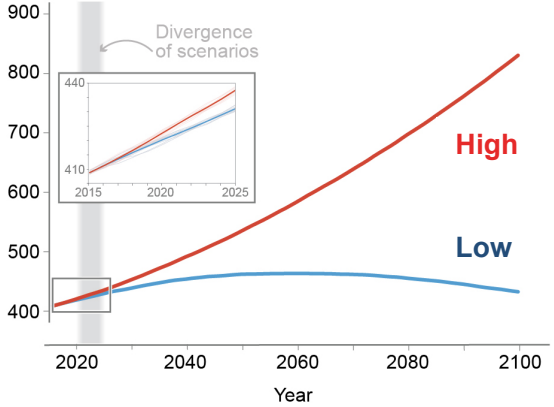
Box TS.7, Figure 1

Differences in trends in global surface temperature would begin to emerge from natural variability within around the next 20 years

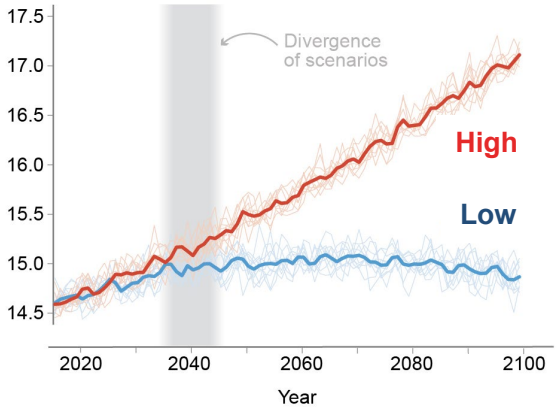
CO_2 emissions (billion tonnes of CO2 per year)



CO_2 concentration in the atmposphere (ppm)



Global surface temperature (°C)



FAQ4.2, Figure 1

Limiting global warming reduces consequences of climate change that can impact society and natural systems

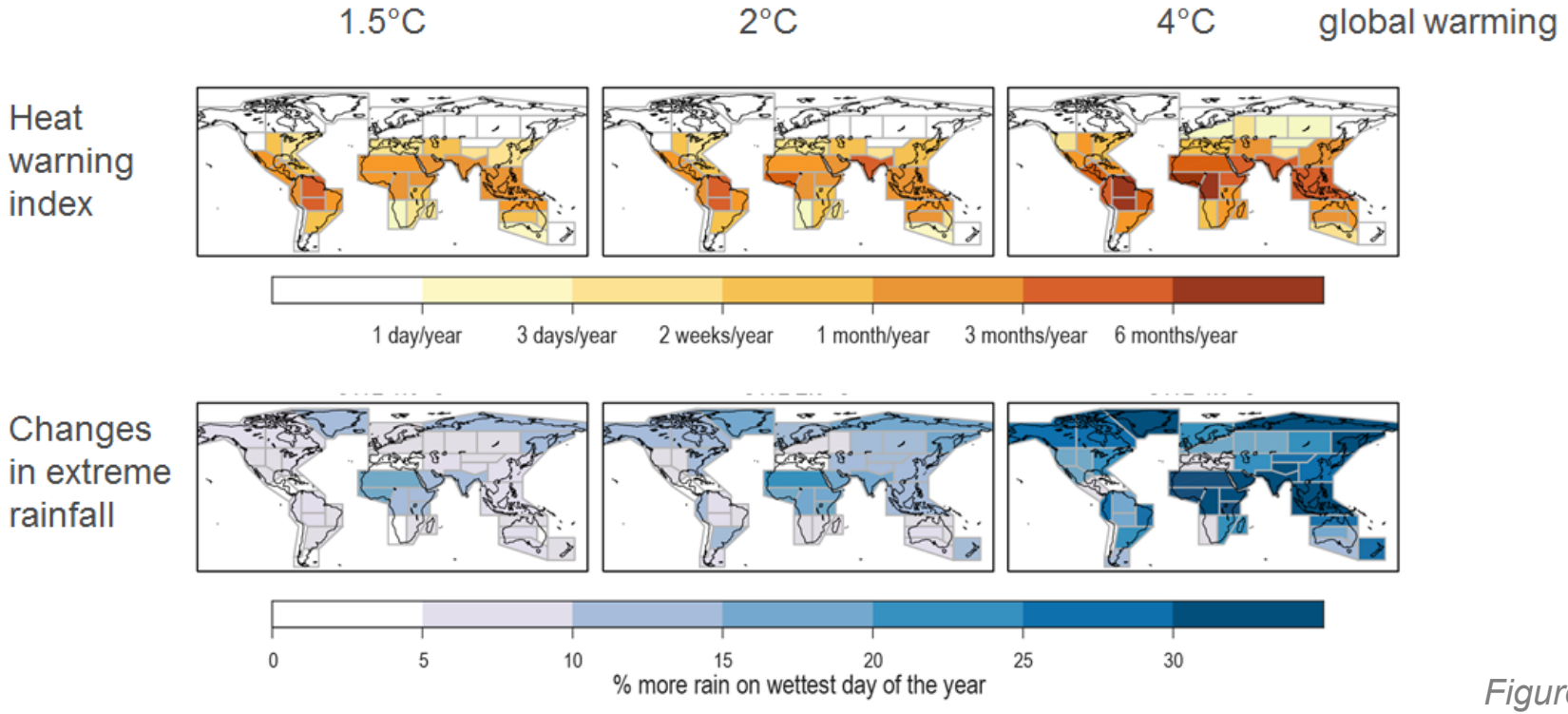


Figure TS.6

Section D - Limiting climate change

- Limiting global warming requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 and strong reductions in other greenhouse gas emissions
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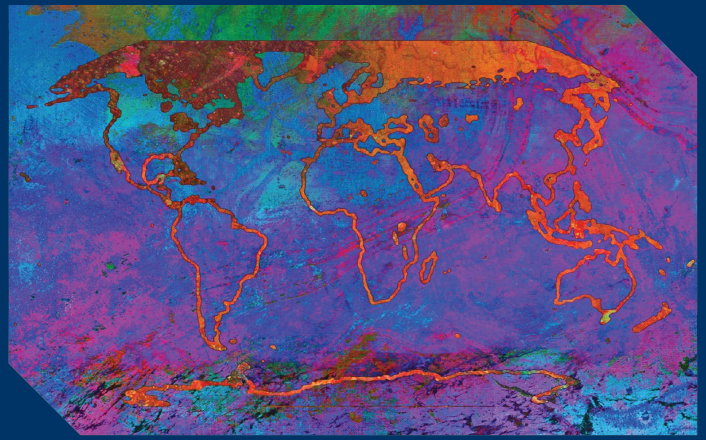
- Effects of strong emission reductions emerge within years for air quality and around 20 years for global surface temperature trends
- The climate we experience in the future depends on our decisions now.



“ The climate we experience in the future depends on our decisions now.

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Thank you.

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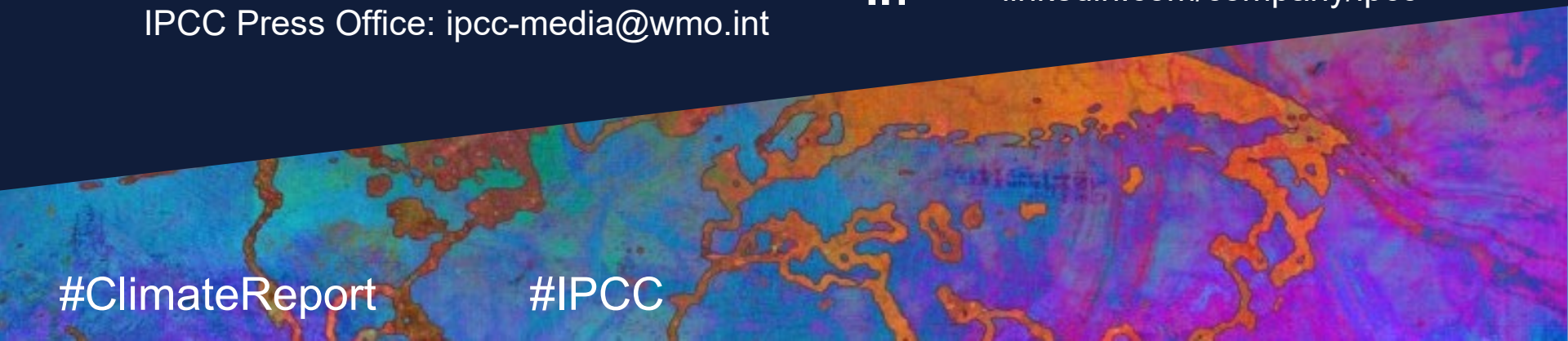

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Report key findings

- Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years.
- It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.
- Climate change is already affecting every region on Earth, in multiple ways. The changes we experience will increase with further warming.
- There's no going back from some changes in the climate system. However, some changes could be slowed and others could be stopped by limiting warming.
- Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C and even 2°C will be beyond reach.
- To limit global warming, strong, rapid, and sustained reductions in CO2, methane, and other greenhouse gases are necessary. This would not only reduce the consequences of climate change but also improve air quality.

Detection of mitigation: COVID-19

Temporary but detectable effects on air pollution (*high confidence*).

Small, temporary increase in total radiative forcing, primarily due to reductions in cooling caused by aerosols arising from human activities (*medium confidence*).

Global and regional climate responses to this temporary forcing are undetectable above natural variability (*high confidence*).

Atmospheric CO2 concentrations continued to rise in 2020, with no detectable decrease in the observed CO2 growth rate (*medium confidence*).