

Global warming - physicist's perspective - 05

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NAUKA O KLIMACIE
DLA SCEPTYCZNYCH



UNIVERSITY
OF WARSAW

WCRP Coupled Model Intercomparison Project (CMIP)



This short movie gives insight into the world of climate modelling, particularly WCRP's initiative CMIP. CMIP provides climate projections that support essential WCRP activities and climate science worldwide, decision and policy-makers communities, in its objective to understand past, present and future climate changes. CMIP and its associated data infrastructure have become essential to the Intergovernmental Panel on Climate Change (IPCC) and other international and national climate assessments.

Earth System Modelling and Observations (ESMO)

[Overview](#)

Working groups

- [Working Group on Coupled Modelling](#)
- [Coupled Model Intercomparison Project](#)
- [Working Group on Subseasonal to Interdecadal Prediction](#)
- [Working Group on Numerical Experimentation](#)
- [Subseasonal to Seasonal Prediction Project](#)
- [Decadal Climate Prediction Project](#)

[Scientific Steering Group](#)

[Activities](#)

[Documents](#)

WGCM

[Overview](#)

[Members](#)

[Meetings](#)

[Publications](#)

Coupled Model Intercomparison Project (CMIP)

- Understanding past, present and future climate -

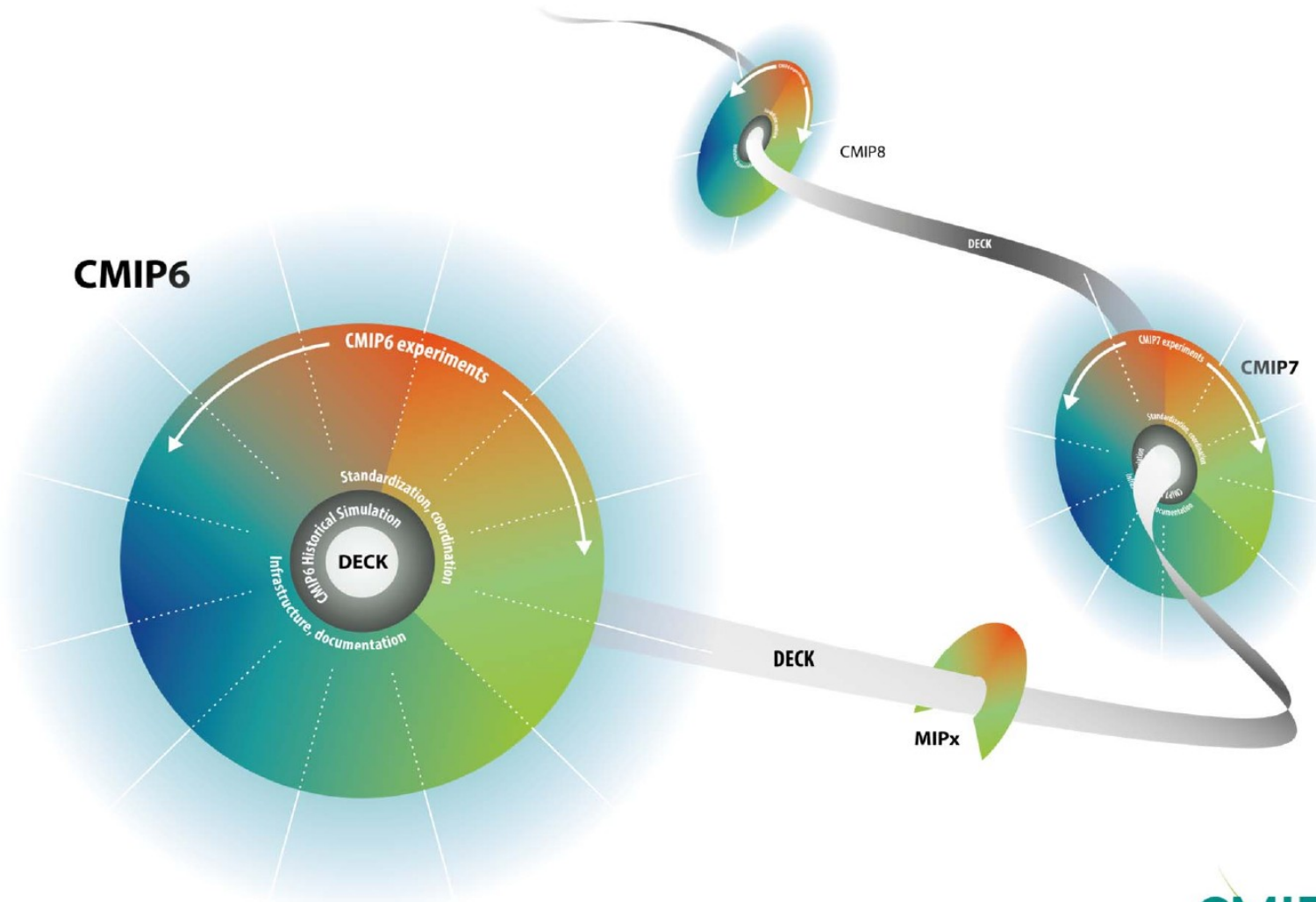
- CMIP is a project of the World Climate Research Programme (**WCRP**)'s Working Group of Coupled Modelling (**WGCM**).
- Since 1995, **CMIP** has coordinated climate model experiments involving multiple international modeling teams worldwide.
- CMIP has led to a better understanding of past, present and future climate change and variability in a **multi-model framework**.
- CMIP defines **common experiment protocols, forcings and output**.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

CMIP6 Design: Scientific Focus

- The **scientific backdrop** for CMIP6 is the **WCRP Grand Science Challenges**:
 1. Clouds, Circulation and Climate Sensitivity
 2. Changes in Cryosphere
 3. Climate Extremes
 4. Regional Sea-level Rise
 5. Water Availability
 6. Near-Term Climate Prediction
 7. Biogeochemical Cycles and Climate Change
- The specific experimental design is focused on **three broad scientific questions**:
 1. How does the Earth System respond to forcing?
 2. What are the origins and consequences of systematic model biases?
 3. How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?

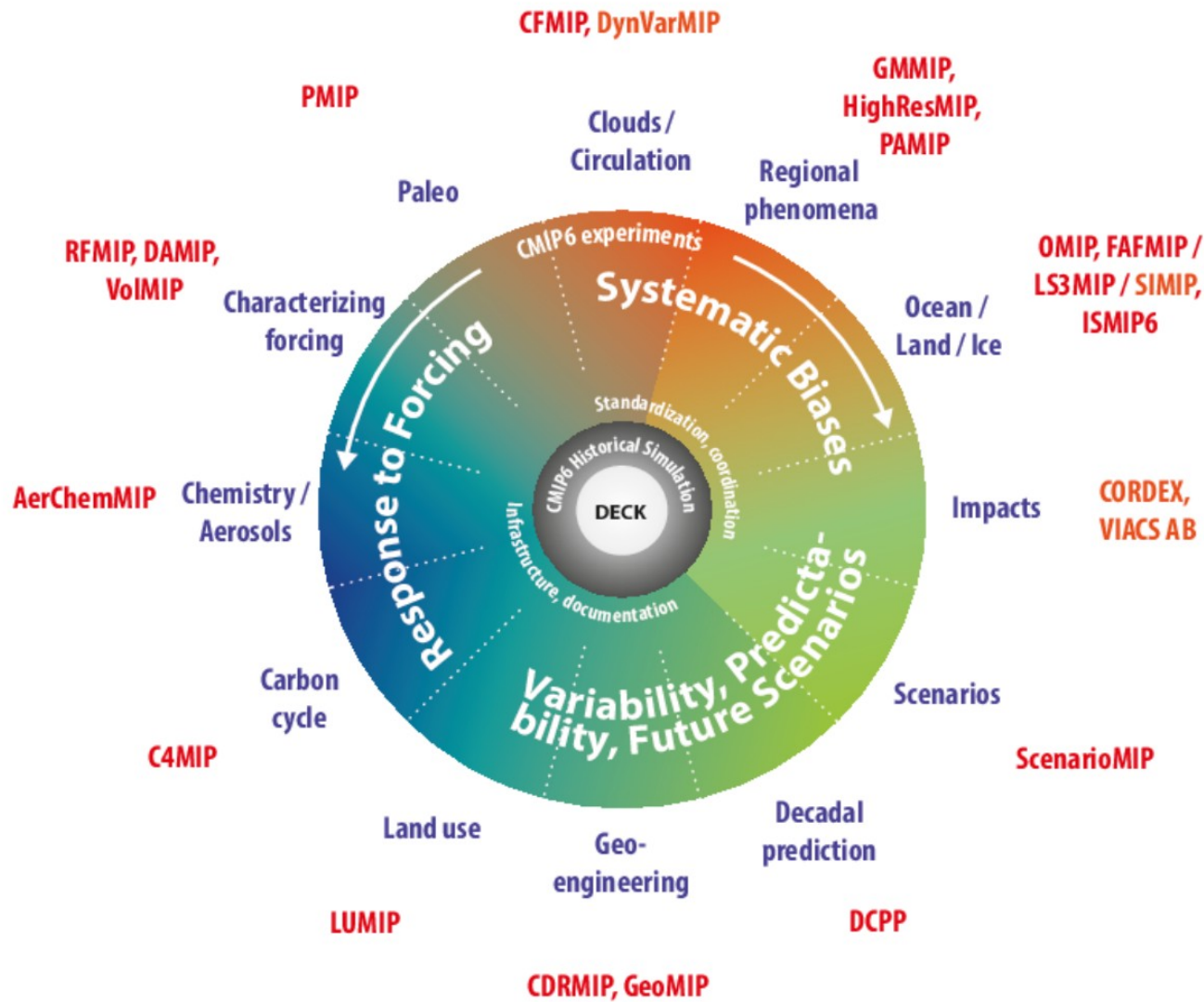
CMIP Continuity

A common suite of experiments for each phase of CMIP provides an opportunity to construct a multi-model ensemble using model output from various phases of CMIP



Eyring et al., *CMIP6 Experimental Design and Organization*, *GMD*, 2016

23 CMIP6-Endorsed MIPs



CMIP6: Participating Model Groups

	Institution	Country		Institution	Country		Institution	Country
1	AWI	Germany	12	DOE	USA	23	MRI	Japan
2	BCC	China	13	EC-Earth-Cons	Europe	24	NASA-GISS	USA
3	BNU	China	14	FGOALS	China	25	NCAR	USA
4	CAMS	China	15	FIO-RONM	China	26	NCC	Norway
5	CasESM	China	16	INM	Russia	27	NERC	UK
6	CCCma	Canada	17	INPE	Brazil	28	NIMS-KMA	Republic of Korea
7	CCCR-IITM	India	18	IPSL	France	29	NOAA-GFDL	USA
8	CMCC	Italy	19	MESSY-Cons	Germany	30	NUIST	China
9	CNRM	France	20	MIROC	Japan	31	TaiESM	Taiwan, China
10	CSIR-CSIRO	South Africa	21	MOHC	UK	32	THU	China
11	CSIRO-BOM	Australia	22	MPI-M	Germany	33	Seoul Nat.Uni	Republic of Korea

New in CMIP:

- 2 new model groups from Germany (AWI, MESSY-Consortium)
- 4 new model groups from China (CAMS, CasESM, NUIST, THU)
- 1 new model group from Brazil (INPE)
- 1 new model group from India (CCCR-IITM)
- 1 new model group from Taiwan, China (TaiESM)
- 1 new model group from USA (DOE)
- 2 new model group from Republic of Korea (NIMS-KMA, SAM0-UNICON)
- 1 new model group from South Africa / Australia (CSIR-CSIRO)

=====

⇒ **13 new model groups so far**

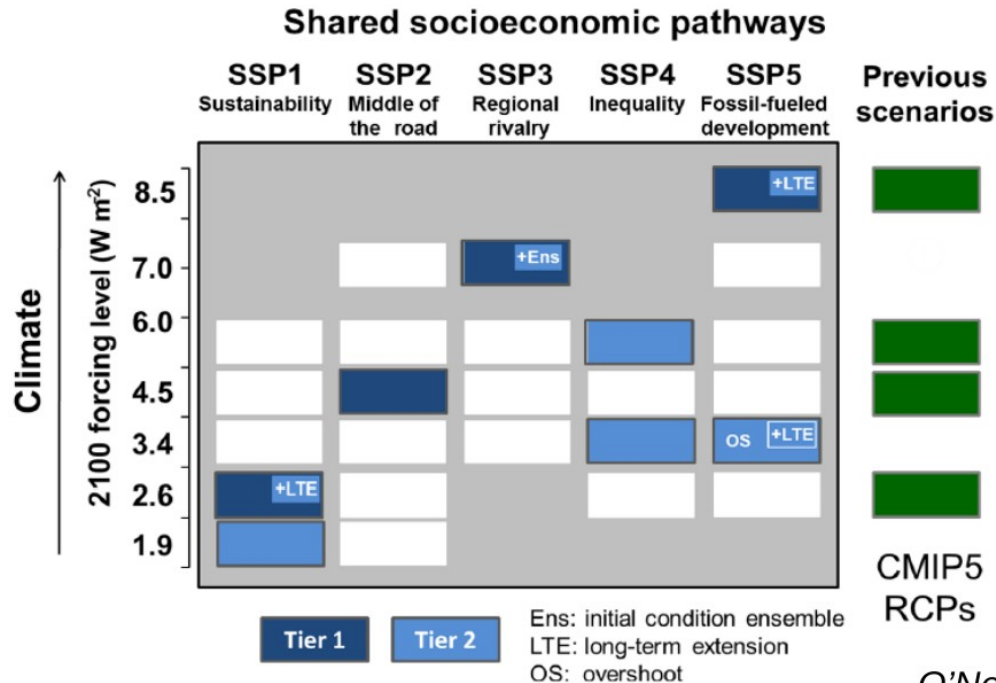
* Other models can join providing DECK and historical simulations are submitted

More models (>70)
 New models
 More complex models
 Higher resolution models

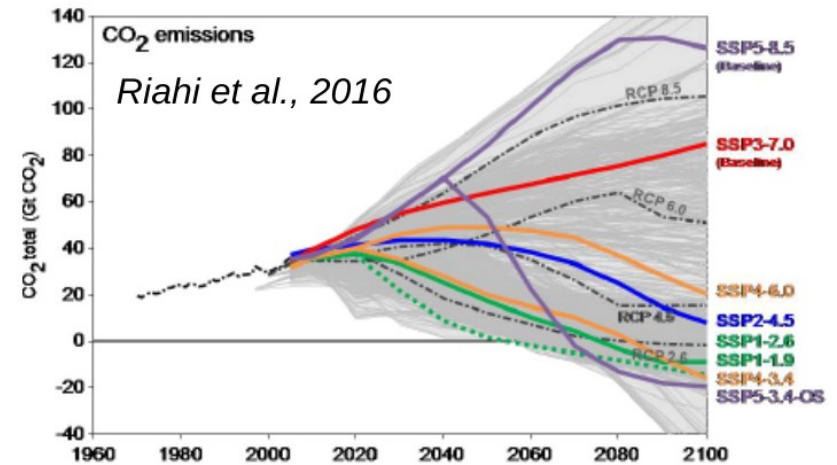


Key Messages: Model Projections / Predictions (2)

SSPs: set of baselines, with future developments in absence of new climate policies beyond those in place today



Future in CMIP6: 2015-2100 plus Extensions to 2300



O'Neill et al., ScenarioMIP for CMIP6, GMD, 2016

ScenarioMIP: New scenarios span a similar range as the RCPs, but fill critical gaps, including

- Role of specific forcings such as land use and short-lived species (air quality)
- The effect of a peak and decline in forcing,
- The consequences of scenarios that limit warming to below 2 °C,

DCPP: Improvements in models, reanalysis, methods of initialization and ensemble generation, and data analysis will provide extended comprehensive decadal predictions



CMIP6 - Coupled Model Intercomparison Project Phase 6

Overview:

The WCRP Working Group on Coupled Modelling (WGCM) oversees the Coupled Model Intercomparison Project, which is now in its 6th phase. Background information about CMIP and its phases can be found on [WGCM website](#) as well as on the [PCMDI-hosted pages](#). An [introductory overview](#) of CMIP6 is also provided by the WGCM.

Practical information for those interested in participating in CMIP6 is provided in [three guides](#), tailored to different groups:

1. [Modelers](#) carrying out CMIP6 simulations,
2. [Data managers](#) responsible for data node operations, and
3. [Data users](#) analyzing and making use of CMIP6 model output

Model output Access:

- First see the [Data Users Guide](#)
- [Summary table](#) of currently available data
- The complete archive of CMIP6 output is accessible from any one of the following portals:
 - USA, PCMDI/LLNL (California) - <https://esgf-node.llnl.gov/projects/cmip6/>
 - France, IPSL - <https://esgf-node.ipsl.upmc.fr/projects/cmip6-ipsl/>
 - Germany, DKRZ - <https://esgf-data.dkrz.de/projects/cmip6-dkrz/>
 - UK, CEDA - <https://esgf-index1.ceda.ac.uk/projects/cmip6-ceda/>

CMIP6 Endorsed MIPs:

- [WCRP Endorsed \(Model Intercomparison Project\) MIPs overview page](#)
- [CMIP6 Ocean Model Intercomparison Project \(OMIP\) overview page](#)

Additional information for CMIP6:

- [CMIP6 license and terms of use](#)

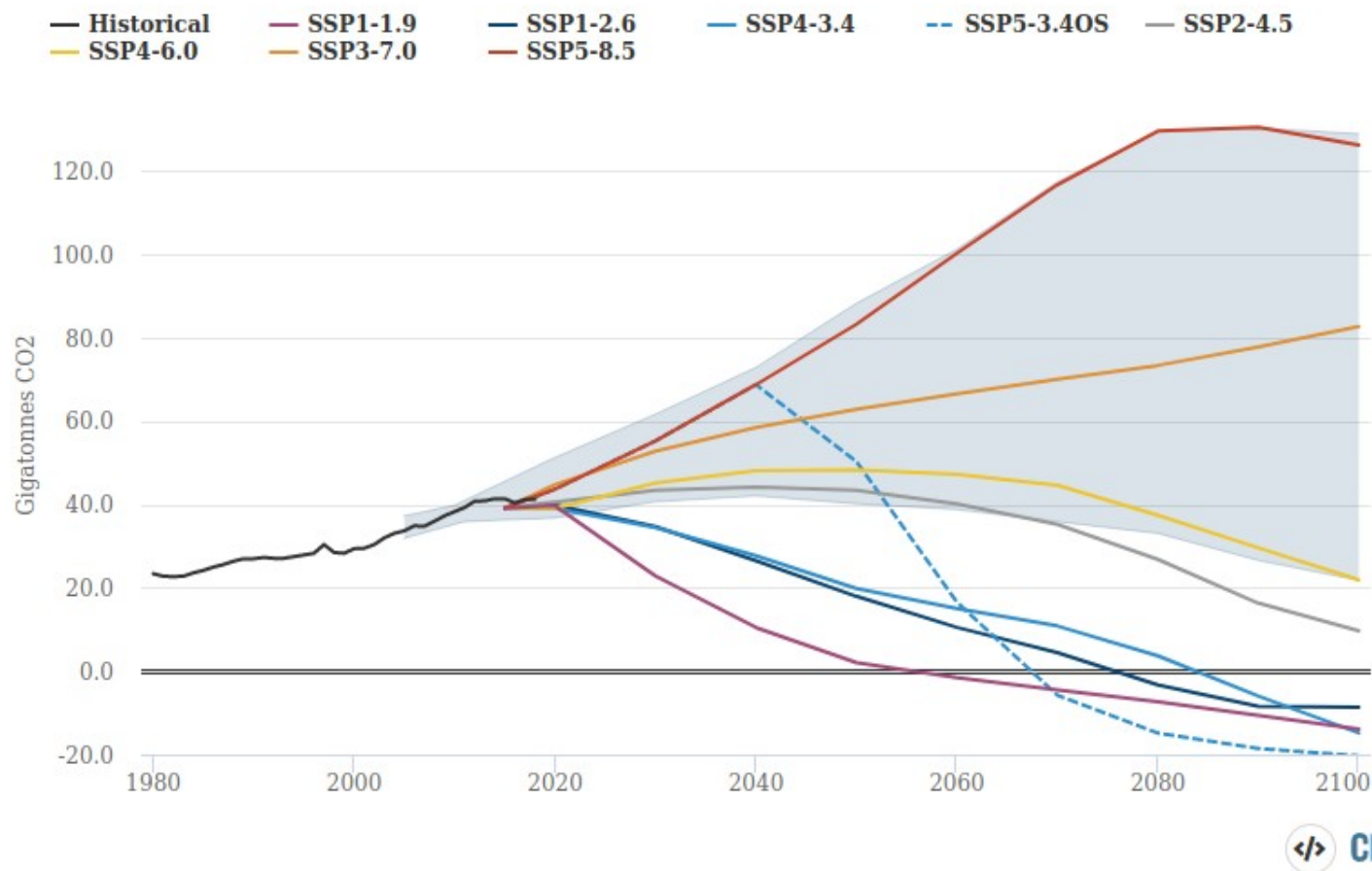
CMIP6 Modeling Groups (click on flags to reveal identity)



Document version: 13 February 2019

A number of new scenarios are also being used for CMIP6 in order to give a wider selection of futures for scientists to simulate. These scenarios are included in the chart below, which shows the annual CO2 emissions assumed under each scenario out to 2100. The new scenarios include SSP1-1.9 (purple line), SSP4-3.4 (blue solid), SSP5-3.4OS (blue dashed) and SSP3-7.0 (orange).

CO2 emissions in CMIP6 scenarios



Future CO2 emissions scenarios featured in CMIP6, as well as historical CO2 emissions (in black). The shaded area represents the range of *no-policy baseline scenarios*. Data from the [SSP database](#); chart by Carbon Brief using [Highcharts](#).

Paleoclimate reference periods. Over the long evolution of Earth’s climate, several periods have received extensive research attention as examples of distinct climate states and rapid climate transitions (Box TS.2, Figure 1). These paleoclimate reference periods represent the present geological era (Cenozoic; past 65 million years) and are used across chapters to help structure the assessment of climate changes prior to industrialization. Cross-Chapter Box 2.1 describes the reference periods, along with a brief account of their climate forcings, and lists where each is discussed in other chapters. Cross-Chapter Box 2.4 summarizes information on one of the reference periods, the mid-Pliocene Warm Period. The Interactive Atlas includes model output from the World Climate Research Programme Coupled Model Intercomparison Project Phase 6 (CMIP6) for four of the paleoclimate reference periods.

Three selected global climate indicators covary across multiple paleoclimate reference periods

(a)

Reference period (*See Interactive Atlas for climate model output)	Age	CO ₂ (ppm)	Temperature (°C)	Sea level (m)
Recent past	1995–2014 CE	360 → 397	0.66 to 1.00	0.15 to 0.25
Approximate pre-industrial	1850–1900 CE	286 → 296	-0.15 to +0.11	-0.03 to 0.00
Last Millennium	850–1850 CE	278 to 285	-0.14 ~ 0.24	-0.05 to 0.03
Mid-Holocene*	6.5–5.5 ka	260 to 268	0.2 to 1.0	-3.5 to +0.5
Last Deglacial Transition	18–11 ka	193 → 271	not assessed	-120 → -50
Last Glacial Maximum*	23–19 ka	188 to 194	-5 to -7	-134 to -125
Last Interglacial*	129–116 ka	266 to 282	0.5 to 1.5	5 to 10
Mid-Pliocene Warm Period*	3.3–3.0 ka	360 to 420	2.5 to 4.0	5 to 25
Early Eocene	53–49 Ma	1150 to 2500	10 to 18	70 to 76
Paleocene-Eocene Thermal Maximum	55.9–55.7 Ma	900 → 2000	10 to 25	not assessed

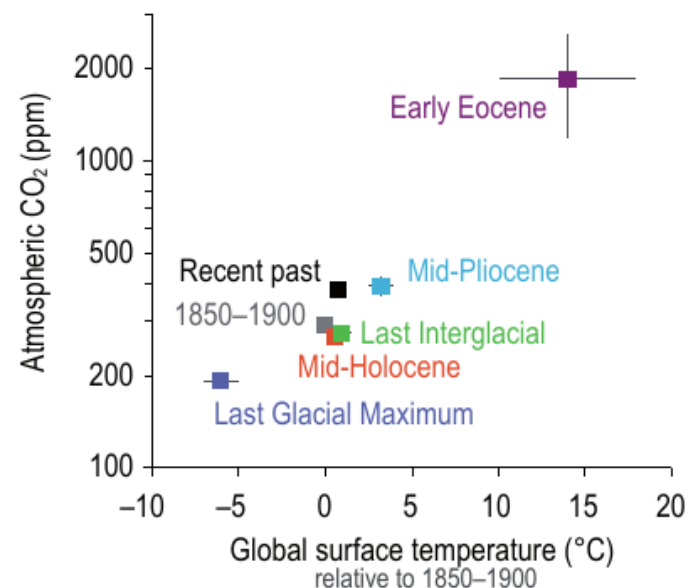
X to Y: *very likely* range (caveats in Figure 2.34)

X → Y: start to end of period, with no stated uncertainty

X ~ Y: lowest and highest values, with not stated uncertainty



(b)



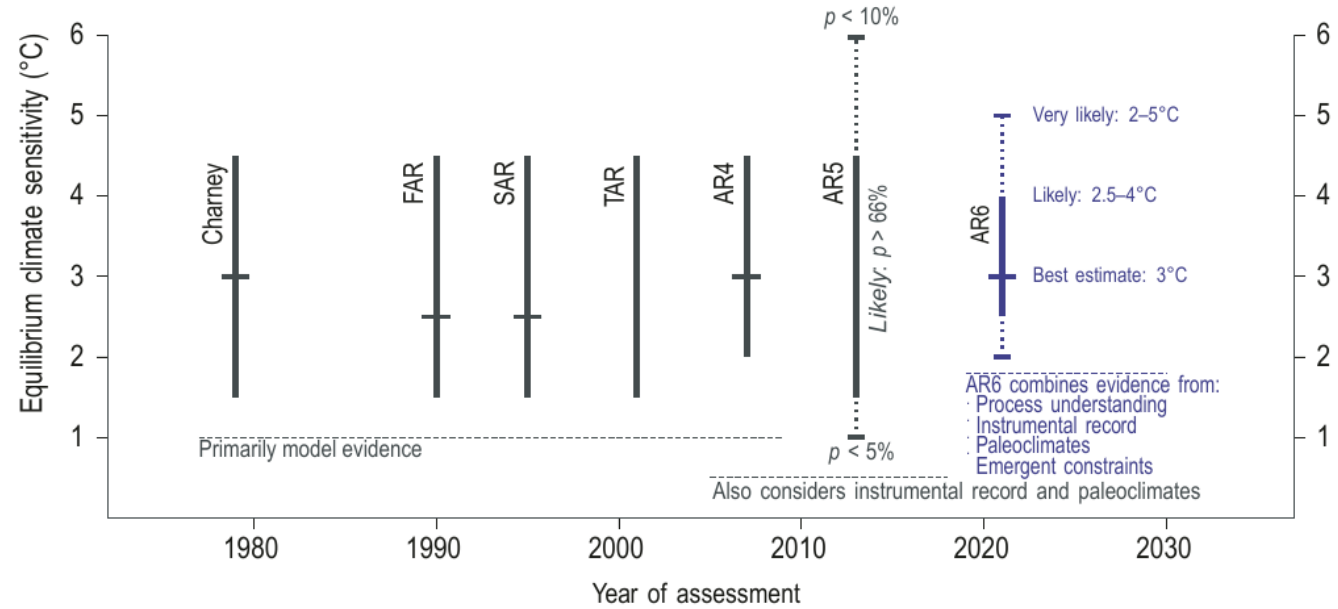
Box TS.2, Figure 1 | Paleoclimate and recent reference periods, with selected key indicators. The intent of this figure is to list the paleoclimate reference periods used in this Report, to summarize three key global climate indicators, and compare CO₂ with global temperature over multiple periods. **(a)** Three large-scale climate indicators (atmospheric CO₂, global surface temperature relative to 1850–1900, and global mean sea level relative to 1900), based on assessments in Chapter 2, with confidence levels ranging from *low* to *very high*. **(b)** Comparison between global surface temperature (relative to 1850–1900) and atmospheric CO₂ concentration (shown on a log scale) for multiple reference periods (mid-points with 5–95% ranges). {2.2.3, 2.3.1.1, 2.3.3.3, Figure 2.34}

TS.3.2 Climate Sensitivity and Earth System Feedbacks

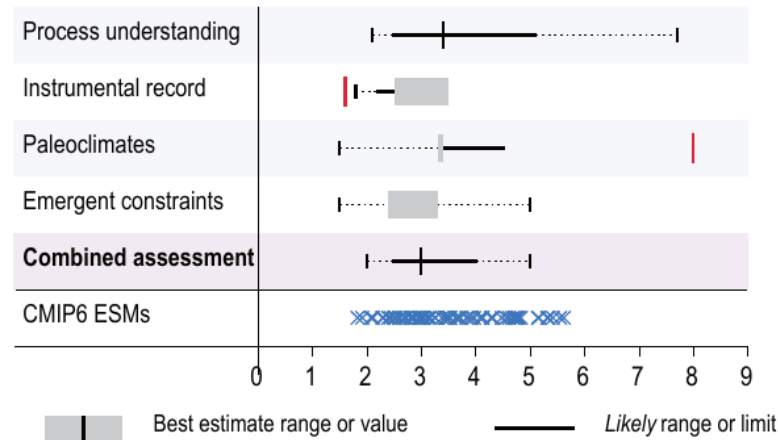
TS.3.2.1 Equilibrium Climate Sensitivity, Transient Climate Response, and Transient Climate Response to Cumulative Carbon-dioxide Emissions

Since AR5, substantial quantitative progress has been made in combining new evidence of Earth's climate sensitivity with improvements in the understanding and quantification of Earth's energy imbalance, the instrumental record of global surface temperature change, paleoclimate change from proxy records, climate feedbacks and their dependence on time scale and climate state. A key advance is the broad agreement across these multiple lines of evidence, supporting a best estimate of equilibrium climate sensitivity of 3°C, with a *very likely* range of 2°C to 5°C. The *likely* range of 2.5°C to 4°C is narrower than the AR5 *likely* range of 1.5°C to 4.5°C. {7.4, 7.5}

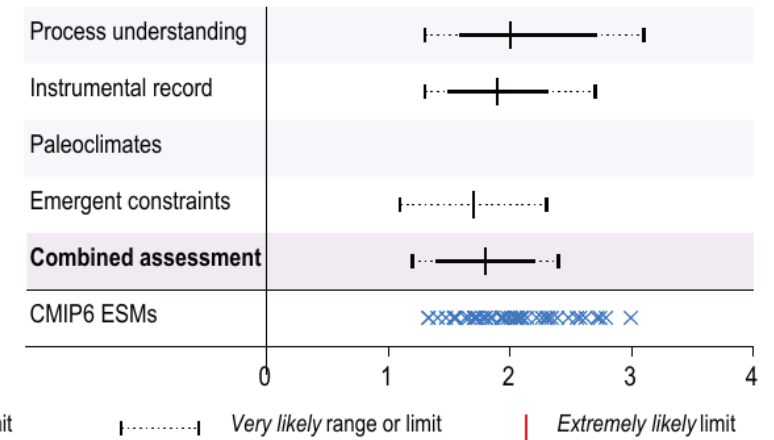
(a) Evolution of equilibrium climate sensitivity assessments from Charney to AR6



(b) Equilibrium climate sensitivity (°C) assessed in AR6 and simulated by CMIP6 ESMs

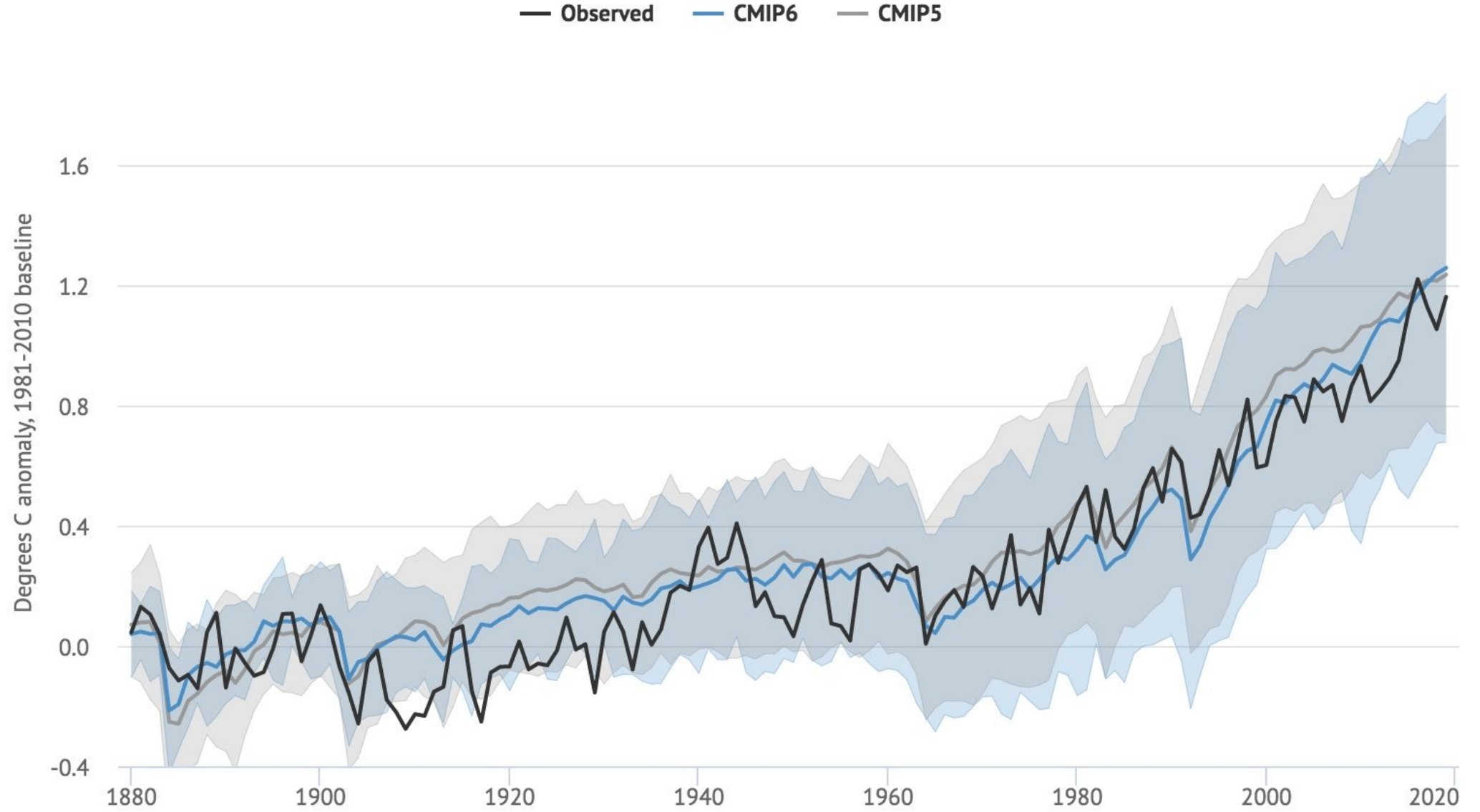


(c) Transient climate response (°C) assessed in AR6 and simulated by CMIP6 ESMs

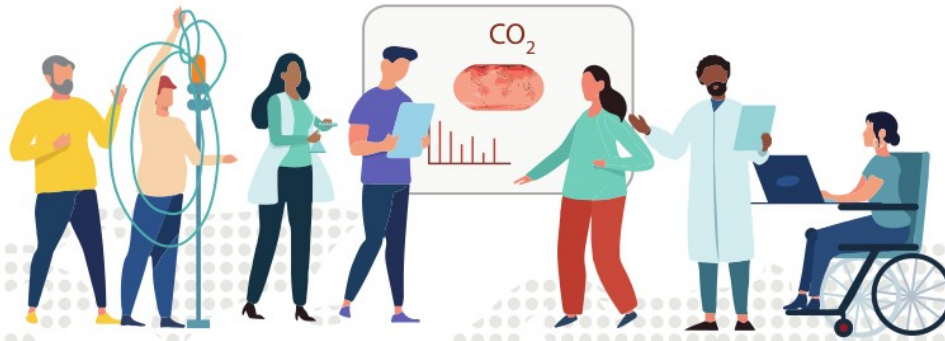


Global surface temperatures 1880-2019: CMIP5, CMIP6 and observations

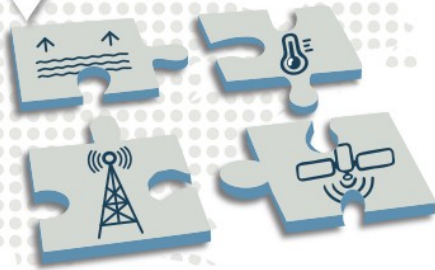
For currently available CMIP6 runs. Observational data from NASA GISTEMP.



CLIMATE RESEARCH



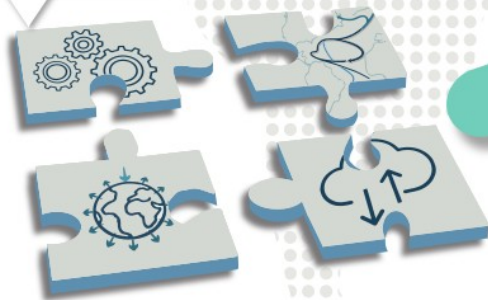
Instruments records



Models



Process understanding



Climate archive

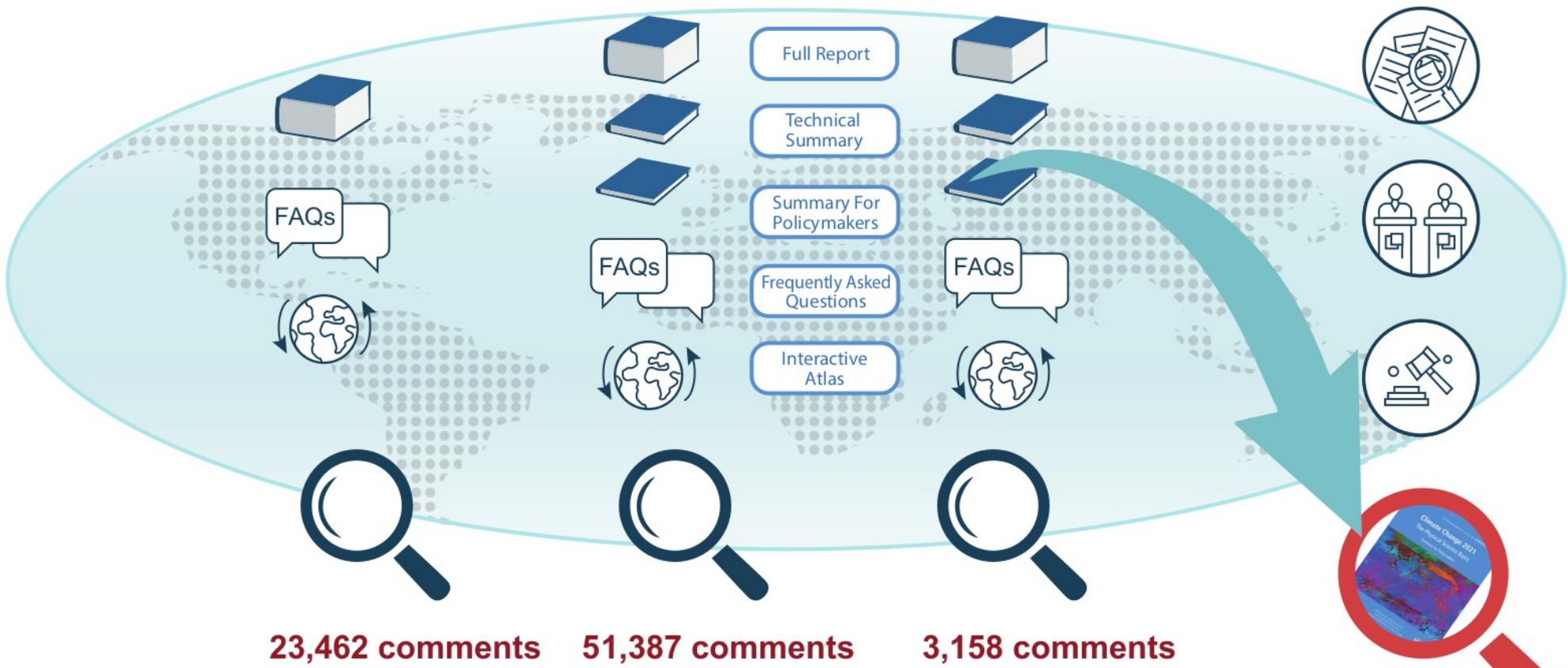


Peer review



IPCC REVIEW PROCESS

- 01 First order draft
- 02 Second order draft
- 03 First governmental distribution
- 04 Approval



23,462 comments

51,387 comments

3,158 comments



1891 individual expert reviewers

47 governments

Review : ensures a robust, objective, and complete assessment

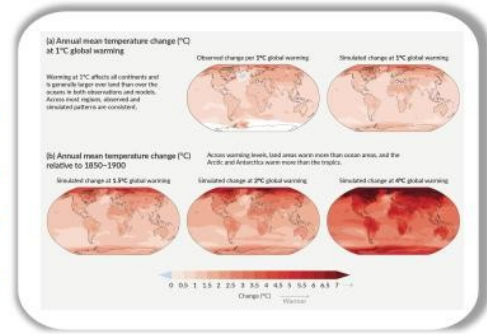
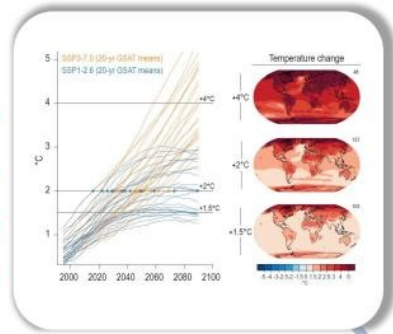
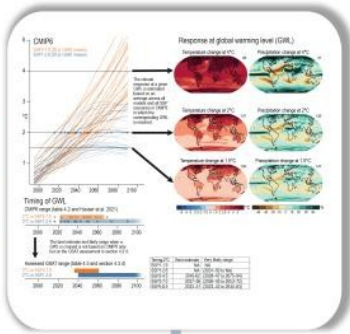
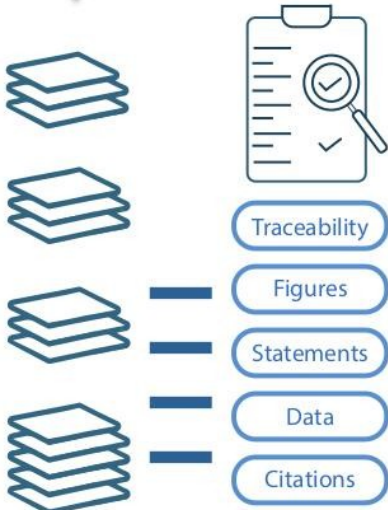
IPCC PRODUCTS AND TRACEABILITY

14 000 publications

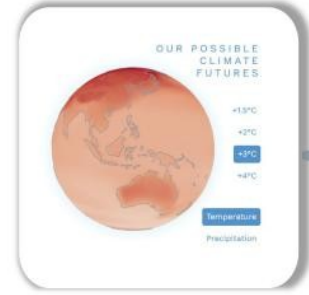
Report
2500 pages

Technical Summary
110 pages

Summary for Policymakers
30 pages



Frequently Asked Questions



Interactive Atlas



Fact sheets



SYNTHESIS REPORT
AR6 Synthesis Report: Climate Change 2023

March 2023

EXPLORE



REPORT
AR6 Climate Change 2022: Mitigation of Climate Change

April 2022

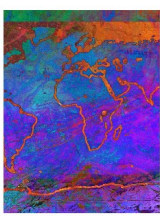
EXPLORE



WORKING GROUP REPORT
AR6 Climate Change 2022: Impacts, Adaptation and Vulnerability

February 2022

EXPLORE



REPORT
AR6 Climate Change 2021: The Physical Science Basis

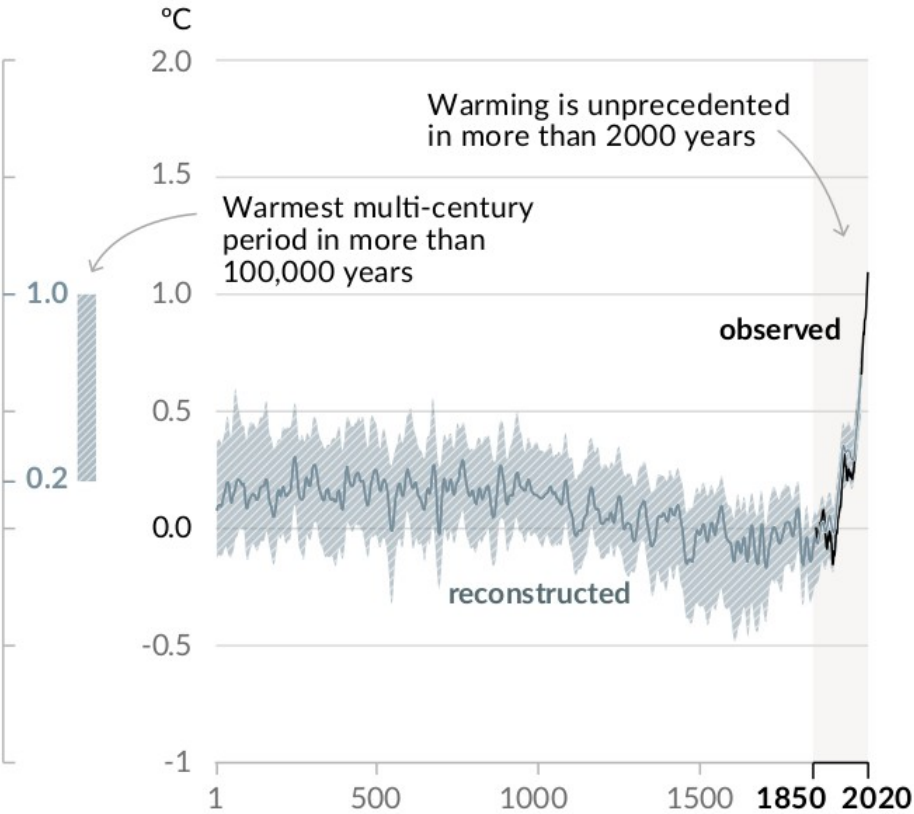
August 2021

EXPLORE

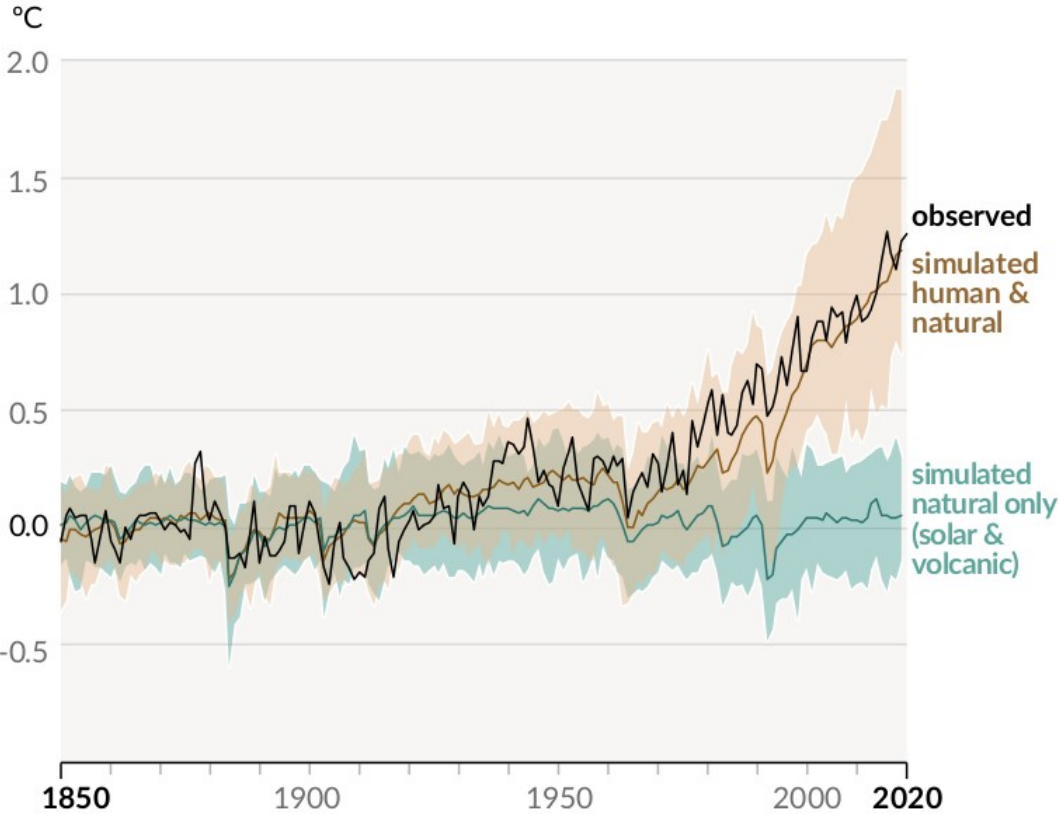
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850-1900

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



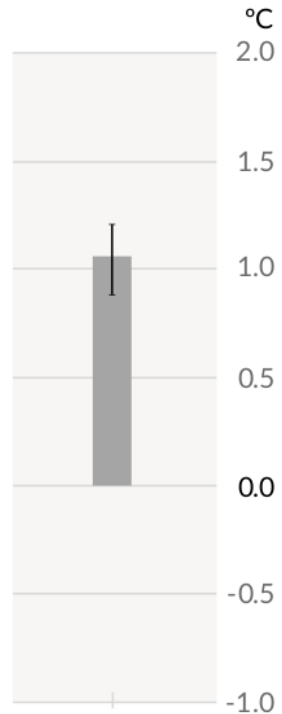
b) Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020)



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

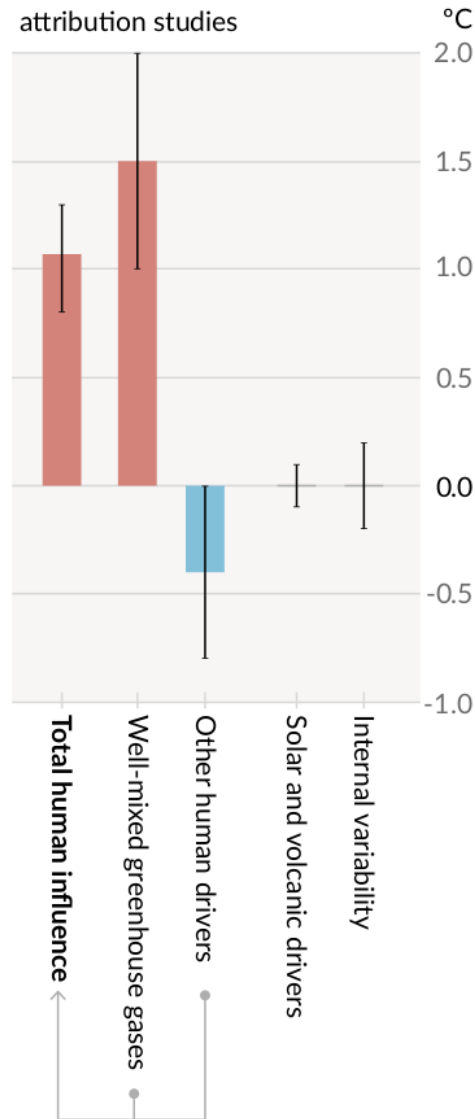
Observed warming

a) Observed warming 2010-2019 relative to 1850-1900

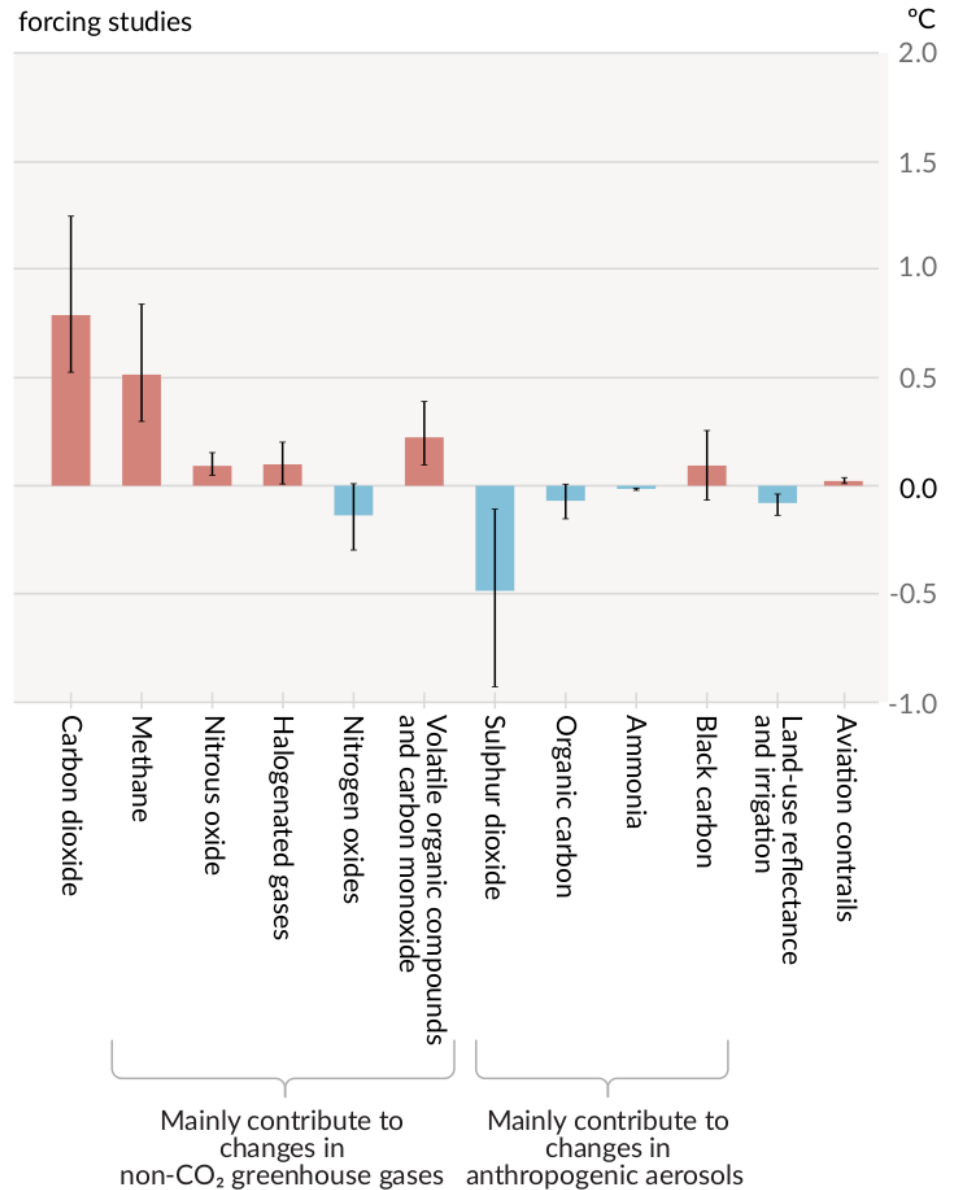


Contributions to warming based on two complementary approaches

b) Aggregated contributions to 2010-2019 warming relative to 1850-1900, assessed from attribution studies

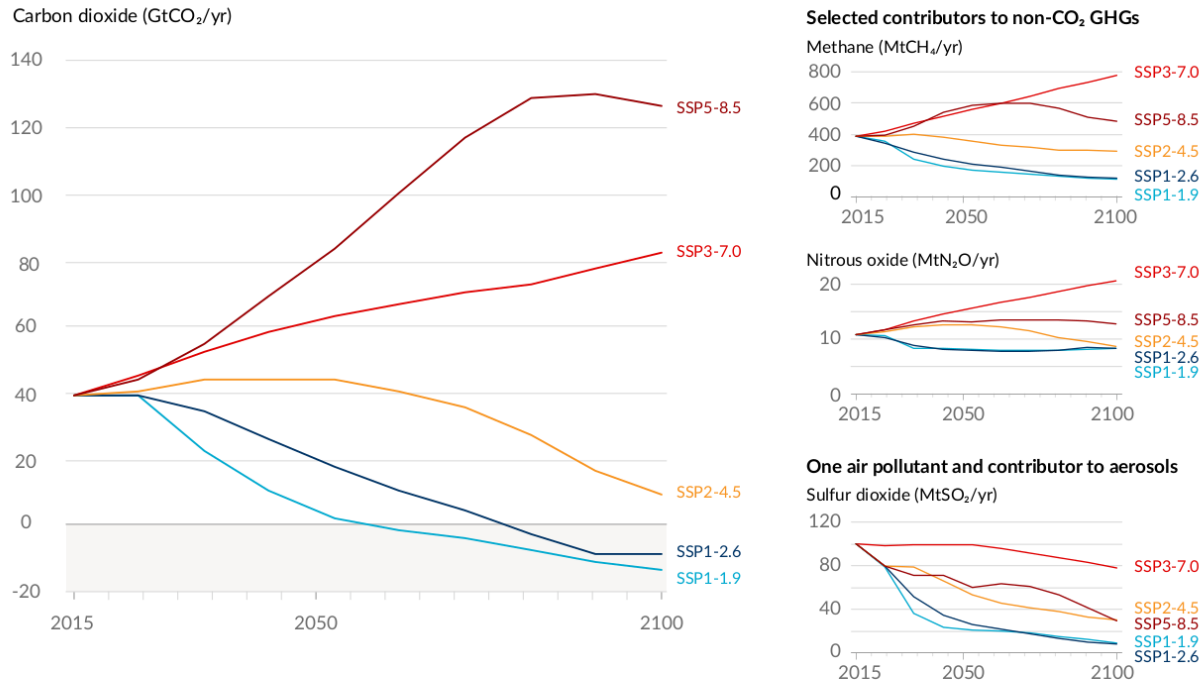


c) Contributions to 2010-2019 warming relative to 1850-1900, assessed from radiative forcing studies



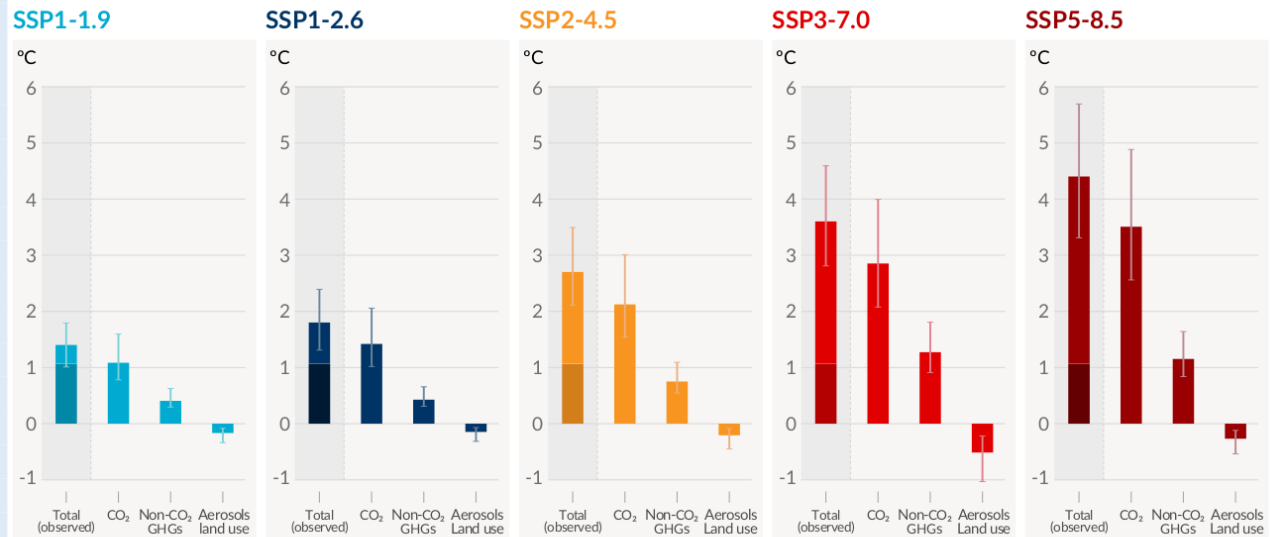
Future emissions cause future additional warming, with total warming dominated by past and future CO₂ emissions

a) Future annual emissions of CO₂ (left) and of a subset of key non-CO₂ drivers (right), across five illustrative scenarios



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

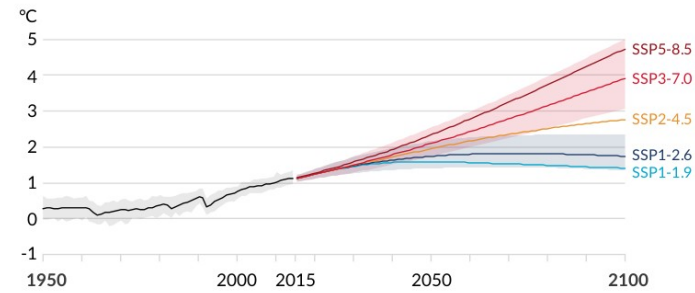
Change in global surface temperature in 2081-2100 relative to 1850-1900 (°C)



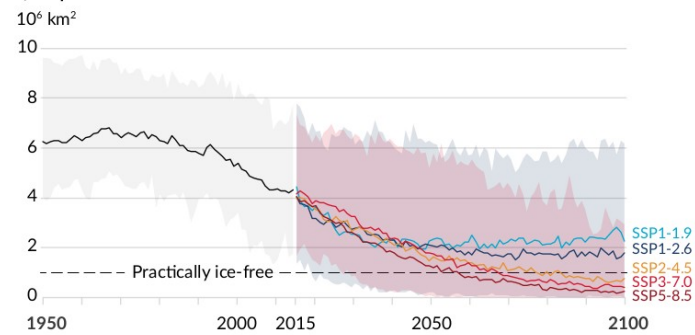
Total warming (observed warming to date in darker shade), warming from CO₂, warming from non-CO₂ GHGs and cooling from changes in aerosols and land use

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

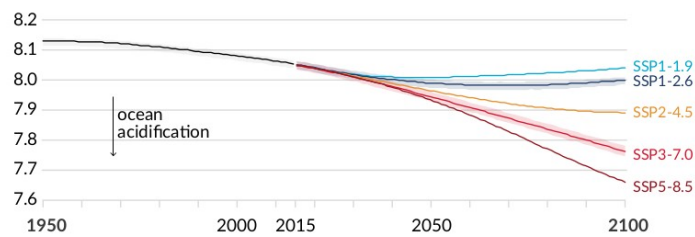
a) Global surface temperature change relative to 1850-1900



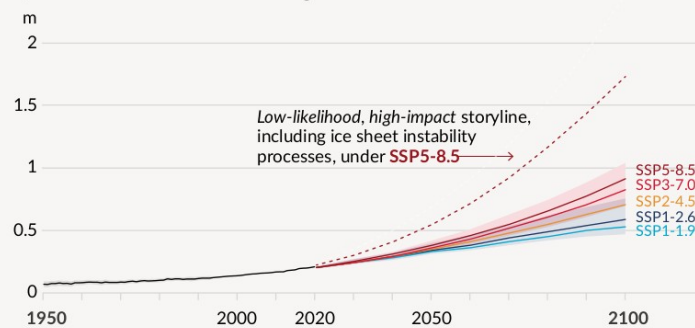
b) September Arctic sea ice area



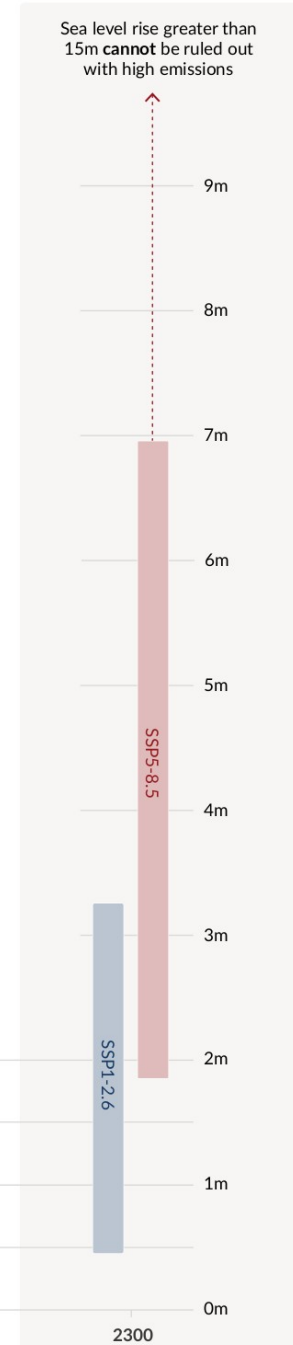
c) Global ocean surface pH (a measure of acidity)



d) Global mean sea level change relative to 1900

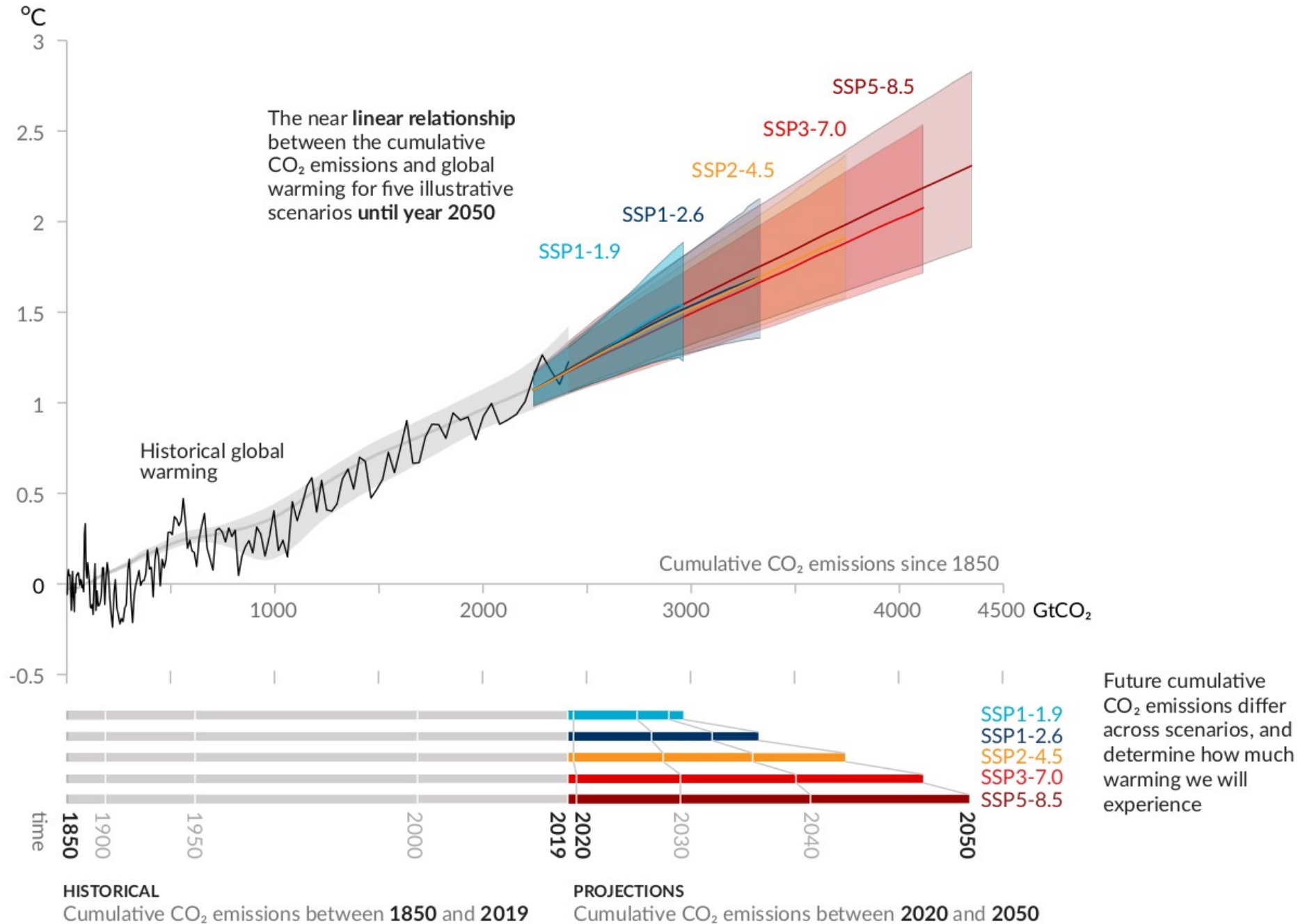


e) Global mean sea level change in 2300 relative to 1900



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)





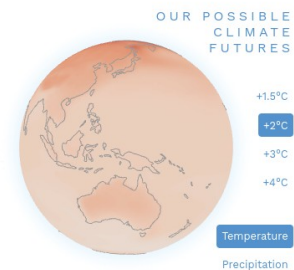
IPCC Working Group I (WGI): Sixth Assessment Report

IPCC WGI Interactive Atlas

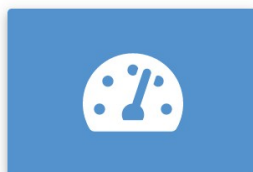
A novel tool for flexible spatial and temporal analyses of much of the observed and projected climate change information underpinning the Working Group I contribution to the Sixth Assessment Report, including regional synthesis for Climatic Impact-Drivers (CIDs).

[Participate in the user testing survey](#)

[Errata and problem reporting](#)



REGIONAL INFORMATION

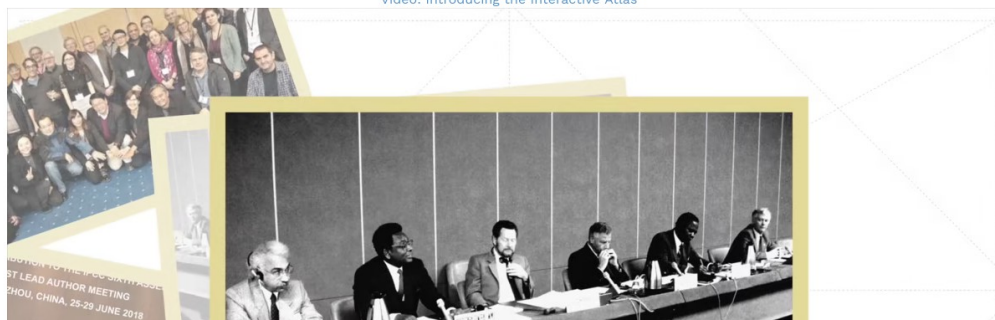


REGIONAL SYNTHESIS



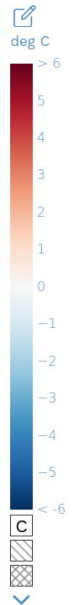
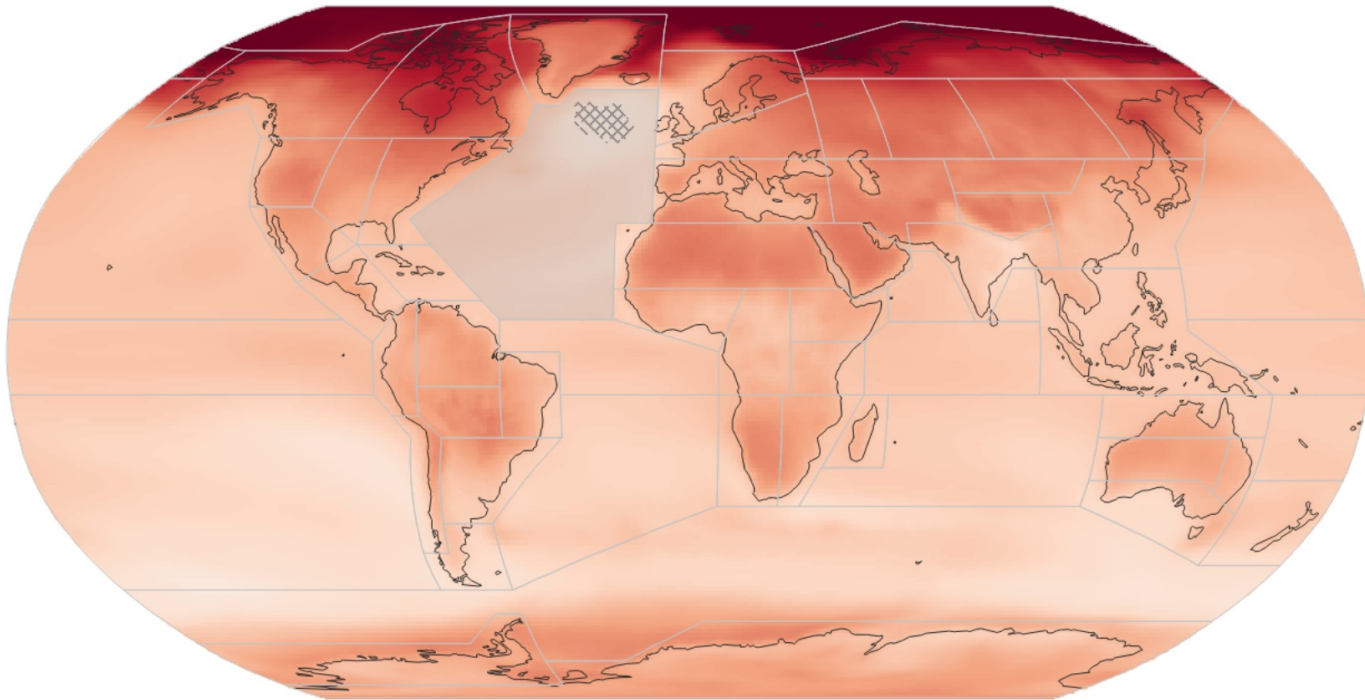
DOCUMENTATION

Video: Introducing the Interactive Atlas



VARIABLE QUANTITY & SCENARIO SEASON

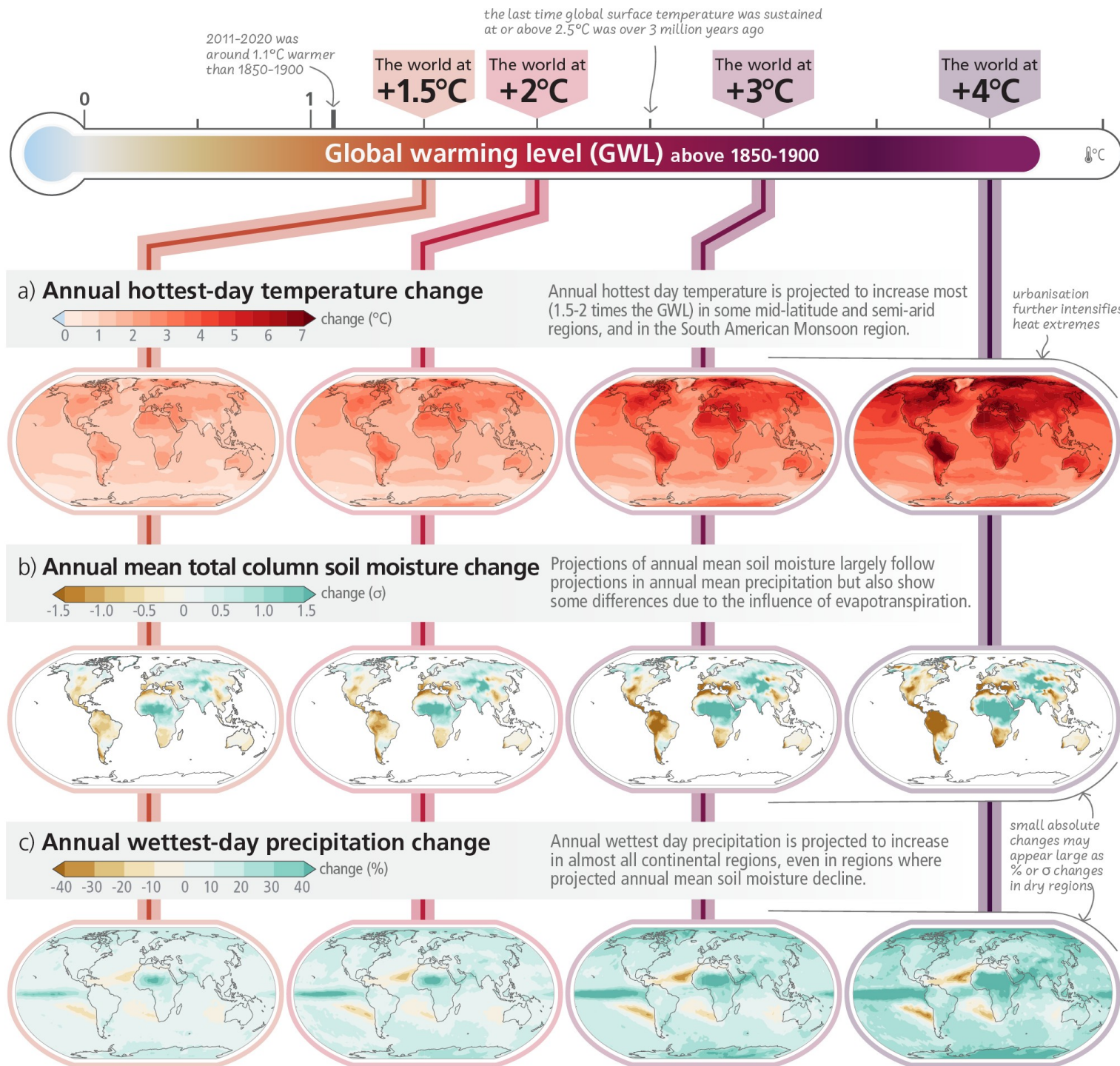
Region Set:
WGI reference-re...
Uncertainty:
Advanced



- + (Zoom In)
- (Zoom Out)
- Map icon
- Layers icon
- Download icon
- Share icon
- Refresh icon
- Mobile view icon
- Fullscreen icon

CMIP6 - Mean temperature (T) Change deg C - Warming 2°C SSP5-8.5 (rel. to 1850-1900) - Annual (34 models)

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



IPCC AR6
synthesis