



Policy response to climate change

Elisabetta Vignati – elisabetta.vignati@gmail.com

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-
Mission 4 “Education and Research” - Component 2: “From research to business” - Investment
3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”



Outline

The role of science in shaping climate policy:

1) From history to present

-  **Historical evolution** of the science-policy interface on climate change
-  **Milestones** leading to the **Paris Agreement (2015)**
-  **Recent EU climate policies** and the European Green Deal
-  **Global emission trends and mitigation potentials:** opportunities, barriers, and pathways forward

2) Scientific methods to provide information to policy

Time is really the only capital that any human being has, and the only thing he can't afford to loose

Thomas Edison (1847-1931)

1860

1890

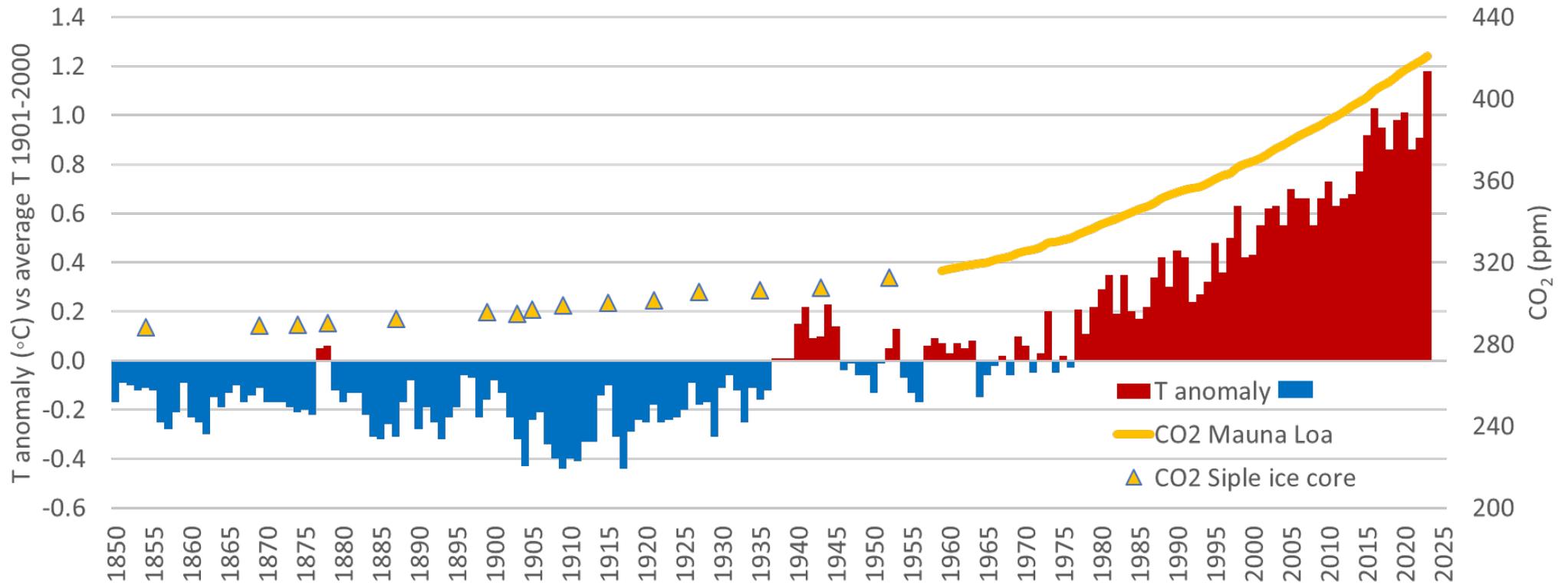
1920

1950

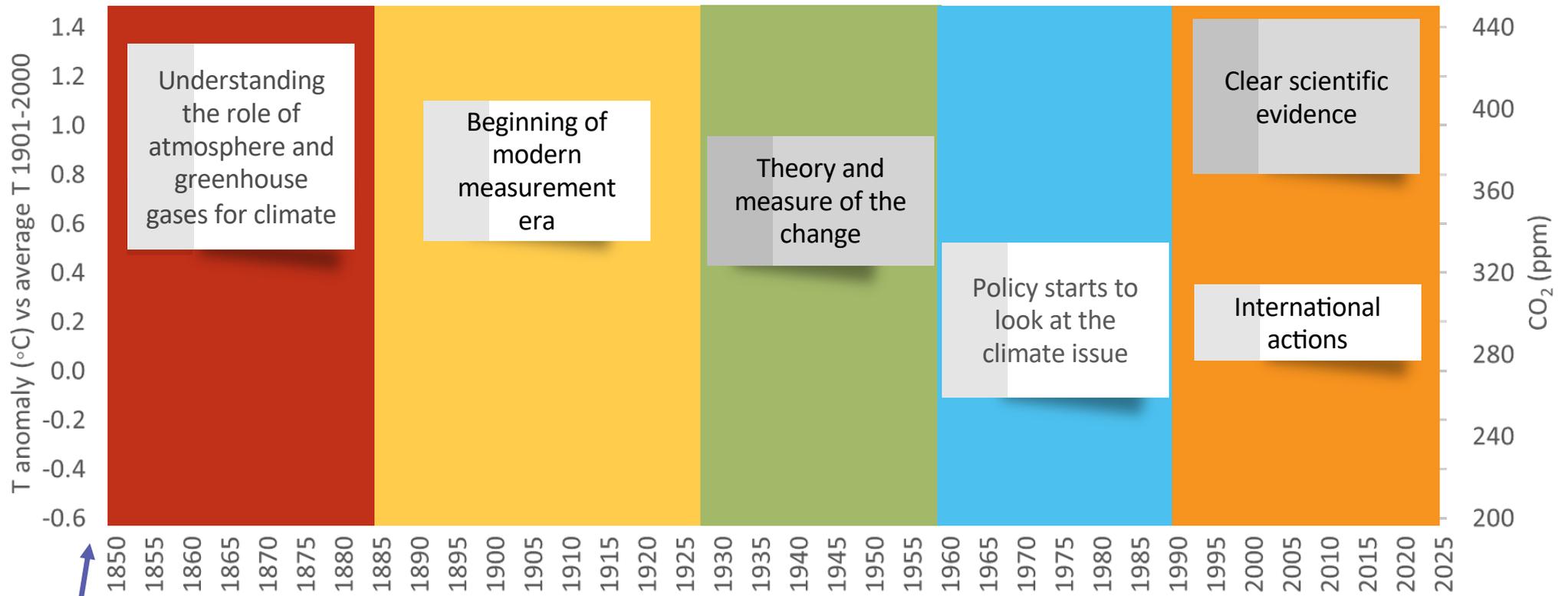
1980

2010

Following the historical lines



Following the historical lines



*however,
before.....*

Anthropogenic effects: Enlightenment thinkers

Jean-Baptiste du Bos, 1719

Artistic genius flourished in suitable climate

Air made also by emanation from earth

Any change in soil and waters could change the atmosphere

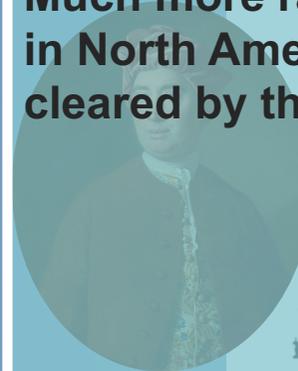
Therefore also deforestation and increased cultivation could change «air» and the wellbeing/culture for a place



David Hume, 1750

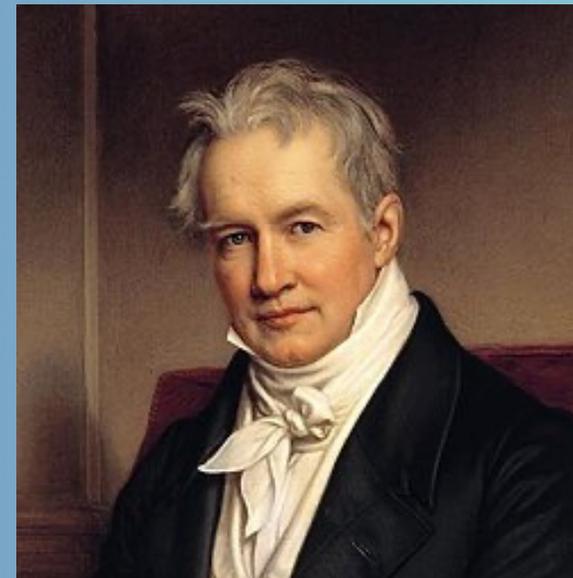
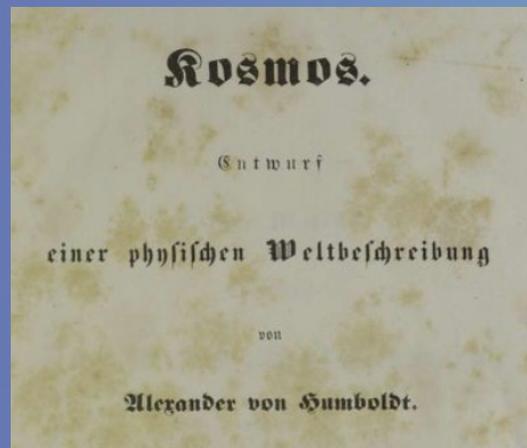
Observed improvement (moderation) of the climate had been caused by the gradual advance of cultivation in the nations of Europe

Much more rapid changes were occurring in North America as the forests were cleared by the European settlers



Understanding factors altering climate

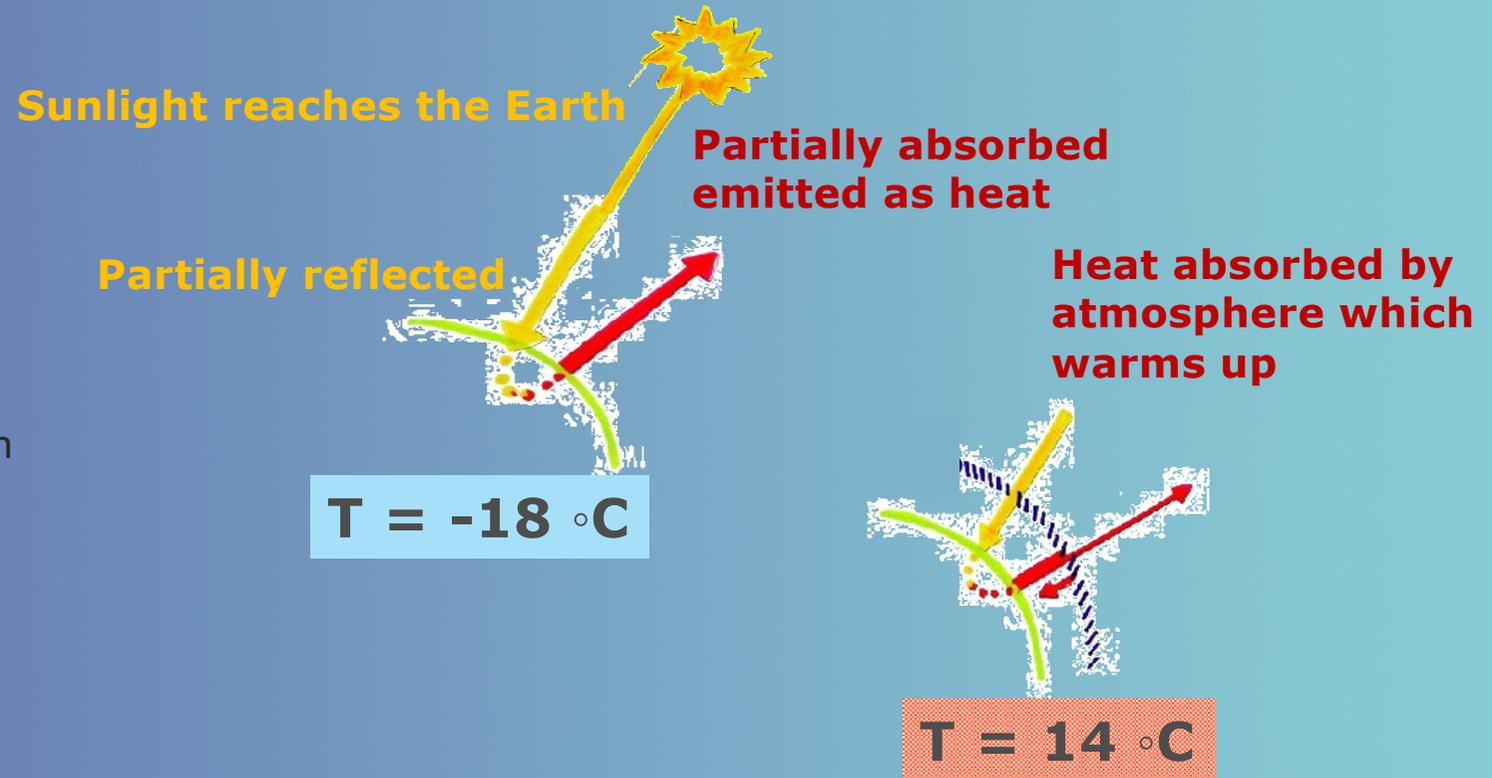
1808 – Alexander von Humboldt discussed how deforestation, irrigation and industrialisation could alter local climates



Describing the «Greenhouse effect»



1824 – Joseph Fourier proposes a natural greenhouse effect as the cause of the temperature on earth

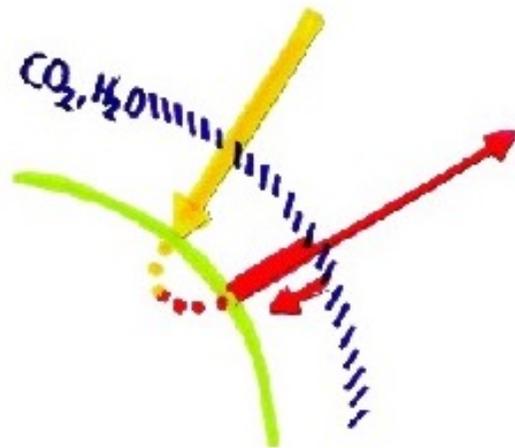


Understanding causes of greenhouse effect

1851 – John Tyndall demonstrates that water vapour and some other gases, including carbon dioxide, absorb infrared radiation while being transparent to visible light: they are the cause of the greenhouse effect



1856 – Eunice Foote demonstrates the absorption of heat from solar radiation by carbon dioxide and water vapour, and also hypothesizes a direct link with their variability as a possible cause of climate change.



Heat absorbed by water vapour and other GHGs and emitted warming the atmosphere



First calculation of warming due to humans

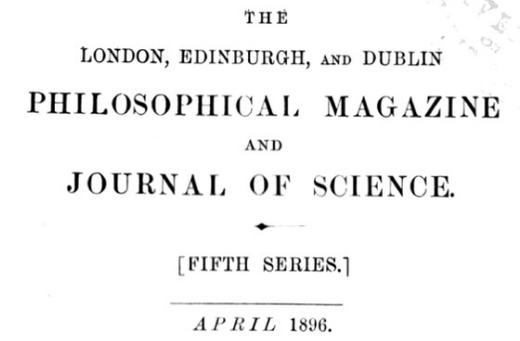


1896 - Svante Arrhenius

Quantifies CO₂ contribution to greenhouse effect

Publishes calculation of the CO₂ global warming: doubling CO₂ concentrations would raise global temperature by 5-6 °C

Hypothesizes that a large part of the **difference in temperature** between the ice ages and the warm “inter-glacials” was due to **carbon dioxide**



XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS*.

Beginning of modern era of measurements

MONTHLY WEATHER REVIEW

Editor, W. J. HUMPHREYS

Vol. 61, No. 9
W.B. No. 1112

SEPTEMBER 1933

CLOSED NOVEMBER 3, 1933
ISSUED DECEMBER 27, 1933

IS OUR CLIMATE CHANGING? A STUDY OF LONG-TIME TEMPERATURE TRENDS

By J. B. KINCER

[Weather Bureau, Washington, D.C., Sept. 29, 1933]

1933 – Joseph Burton Kincer

“All of these confirm the general statement that we are in the midst of a period of abnormal warmth, which has come on more or less gradually for many years”

He did not suggest a reason

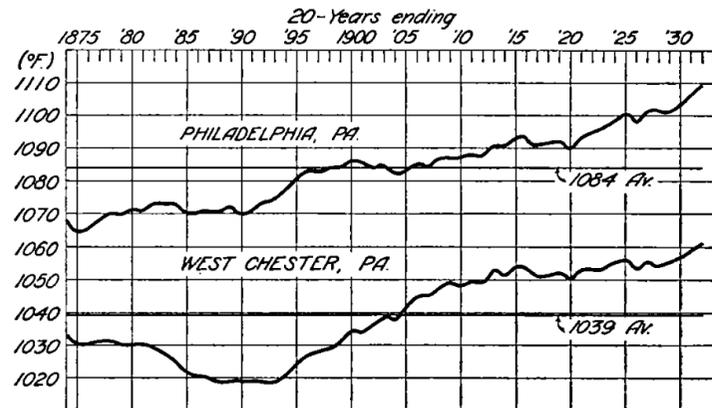
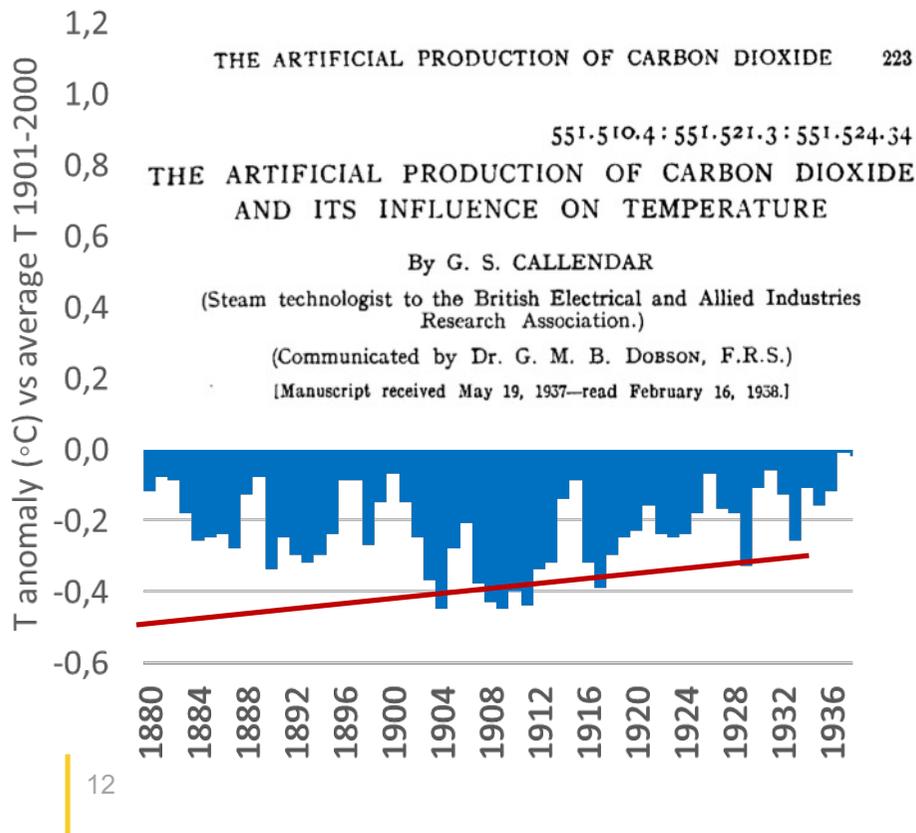


FIGURE 5.—20-year moving temperature summations; Philadelphia and West Chester, Pa. Data in table 1.



Beginning of modern era of measurements



1938 - Guy Stewart Callendar

Uses 200 meteorological stations data: T increased by **0.005 °C/year** in last half century

He connects it to **human emitted CO₂**.

$\frac{3}{4}$ of emitted fossil fuel CO₂ (150,000 million tons) had **remained** in the atmosphere

Theory and monitoring of the changes

The Carbon Dioxide Theory of Climatic Change

By GILBERT N. PLASS

The Johns Hopkins University, Baltimore, Md.¹

(Manuscript received August 9 1955)

1955 Increase by **3.6 °C** by doubling atmospheric CO₂; industrial processes and other **human activities** are increasing CO₂ concentration at the rate of nearly **30 % per century** and causing the average temperature to rise **1.1 °C per century**.



Carbon Dioxide Exchange Between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO₂ during the Past Decades

By ROGER REVELLE and HANS E. SUESS, Scripps Institution of Oceanography, University of California, La Jolla, California

(Manuscript received September 4, 1956)

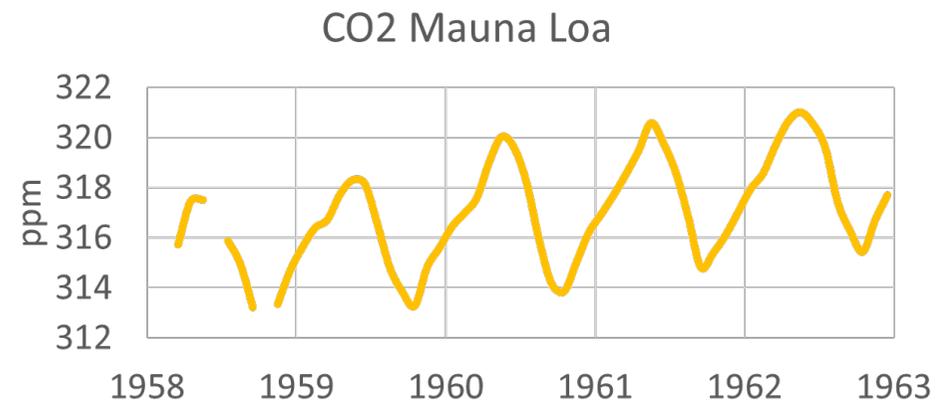
1957 Oceans could not **absorb** the fossil fuels CO₂; an **increase** by 20 to 40% of atmospheric CO₂ could be anticipated.



Theory and monitoring of the changes



1958 - C.D. Keeling starts systematic CO₂ measurements at Mauna Loa; demonstrating its **increase** in 4 years



Restoring the Quality of Our Environment

USA President
Lyndon B. Johnson's
Science Advisory
Committee Report

1965

Policy interest in climate issue

01

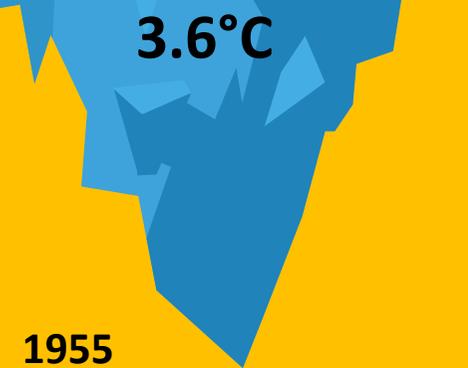
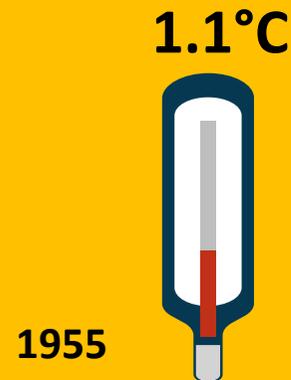
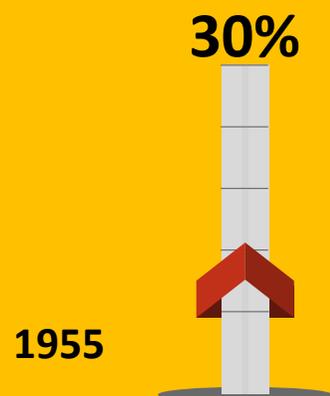
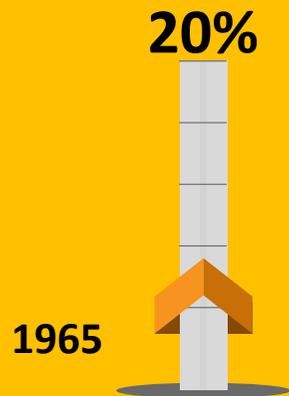
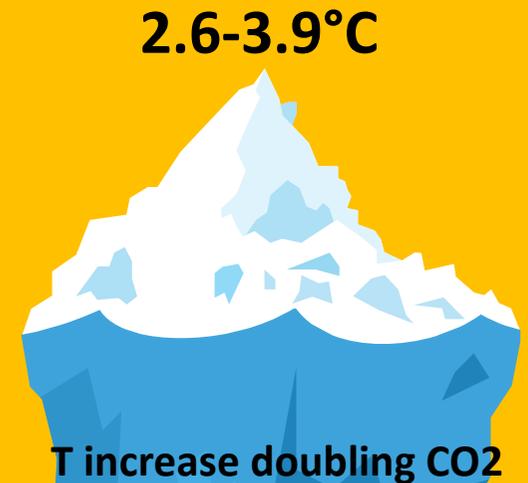
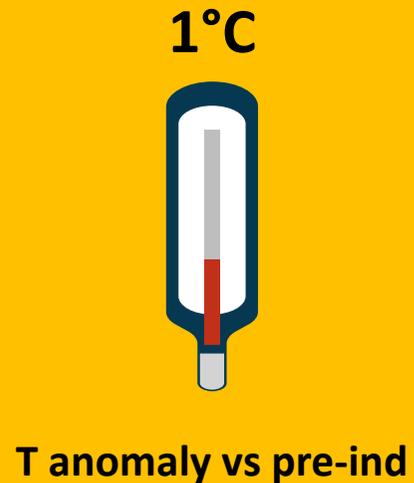
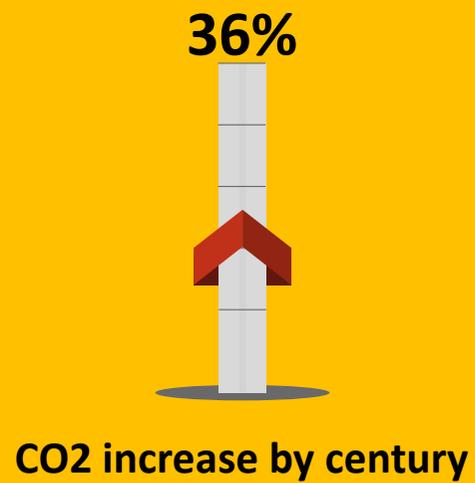
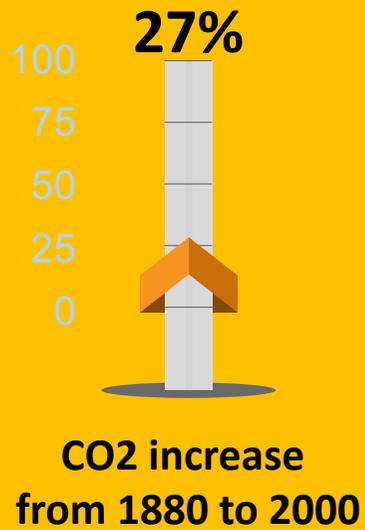
“**measurable**” effect of fossil fuel combustion on the increase in atmospheric CO₂

03

Conclusions: “By the year **2000** the increase in atmospheric CO₂ will be close to **25%**. This may be sufficient to produce measurable and perhaps marked changes in climate, and will **almost certainly cause** significant changes in the temperature and other properties of the stratosphere.”

02

It is added to the atmosphere by the **burning** of coal, oil, and natural gas at the rate of 6 billion tons a year.” increasing the quantity of CO₂ in the atmosphere and ocean **by 7%** since pre-industrial time (up to 1960)



Science meets politics: towards Intergovernmental Panel on Climate Change

1972

UN 1st Earth Summit

Declaration raised climate change issue for the first time, warning Governments to be aware of activities that could lead to climate change and evaluate the likelihood and magnitude of climatic effects.

1985

UN Workshops

Organised by WMO and UNEP. Recommended that 'scientists and policymakers should begin active collaboration to explore the effectiveness of alternative policies and adjustments'

1988

WMO call for IPCC

WMO Secretary General invited Member Countries to agree on the establishment of the Intergovernmental Panel on Climate Change

1979

Declaration "Carbon dioxide plays a fundamental role of ... earth temperature, ... plausible that an increased amount of CO2 can contribute to a gradual warming". No calls for policy action

1st World Climate Conf.

1986

Involving UNEP, WMO and USA, on development of a more effective mechanism for climate issue assessment

Discussions

First session of IPCC, 1988, Photo IPCC

A fundamental hearing before USA Senate

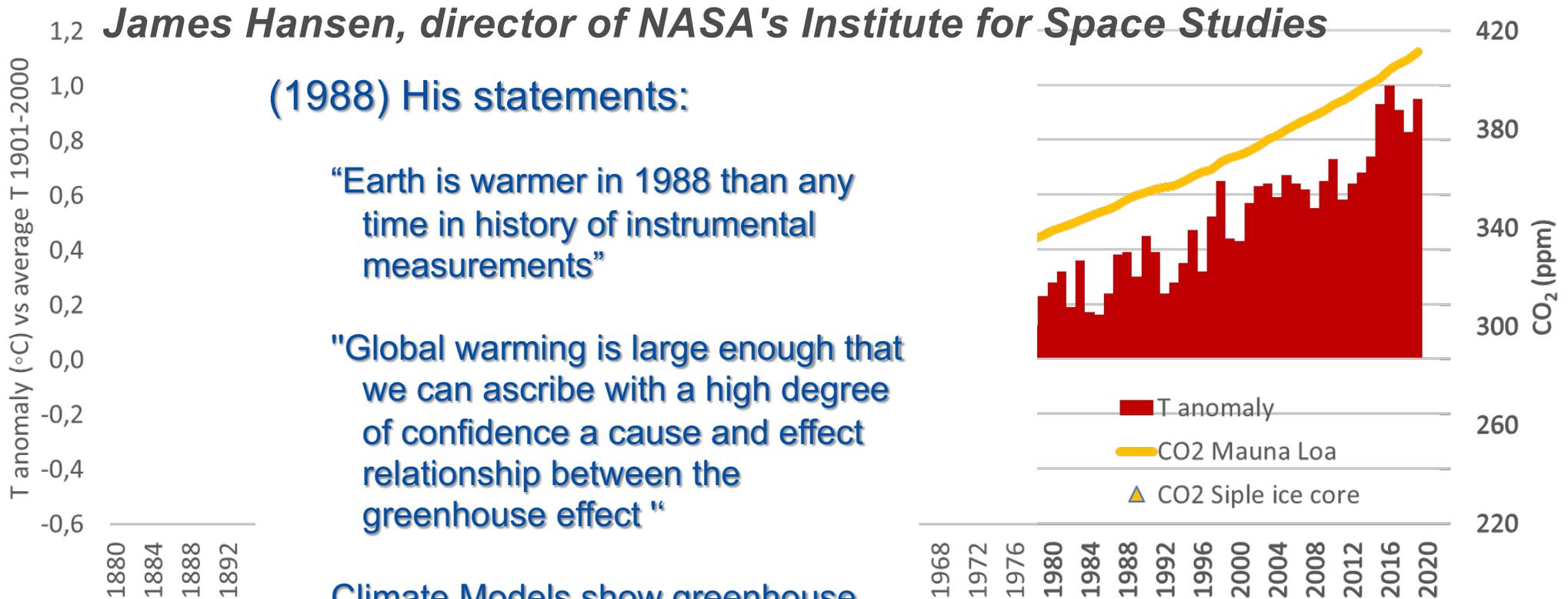
James Hansen, director of NASA's Institute for Space Studies

(1988) His statements:

"Earth is warmer in 1988 than any time in history of instrumental measurements"

"Global warming is large enough that we can ascribe with a high degree of confidence a cause and effect relationship between the greenhouse effect"

Climate Models show greenhouse effect is already large enough to begin affecting extreme events



Margaret Thatcher urges a climate pact at UN

A

STOP ACCUMULATION GHG

But at least we have recognised that reducing and eventually stopping the emission of CFCs is one positive thing we can do about the menacing accumulation of greenhouse gases.

C

MONITOR BINDING PROTOCOLS

These protocols must be binding and there must be effective regimes to supervise and monitor their application

B

A FRAMEWORK CONVENTION

The most pressing task which faces us at the international level is to negotiate a framework convention on climate change—a sort of good conduct guide for all nations

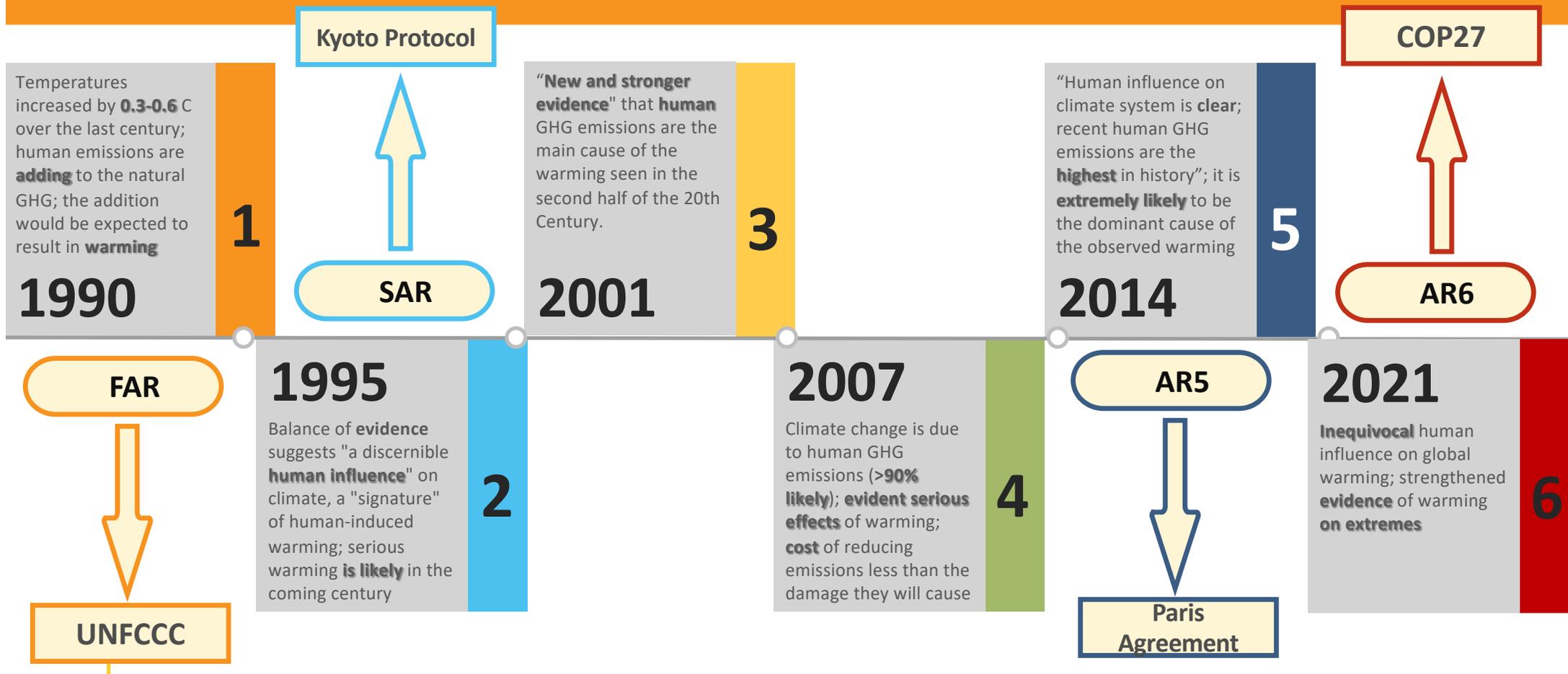
D

IPCC FOR NEGOTIATIONS

The United Kingdom therefore proposes that we prolong the role of the Inter-governmental Panel on Climate Change after it submits its report next year, so that it can provide an authoritative scientific base for the negotiation of this and other protocols

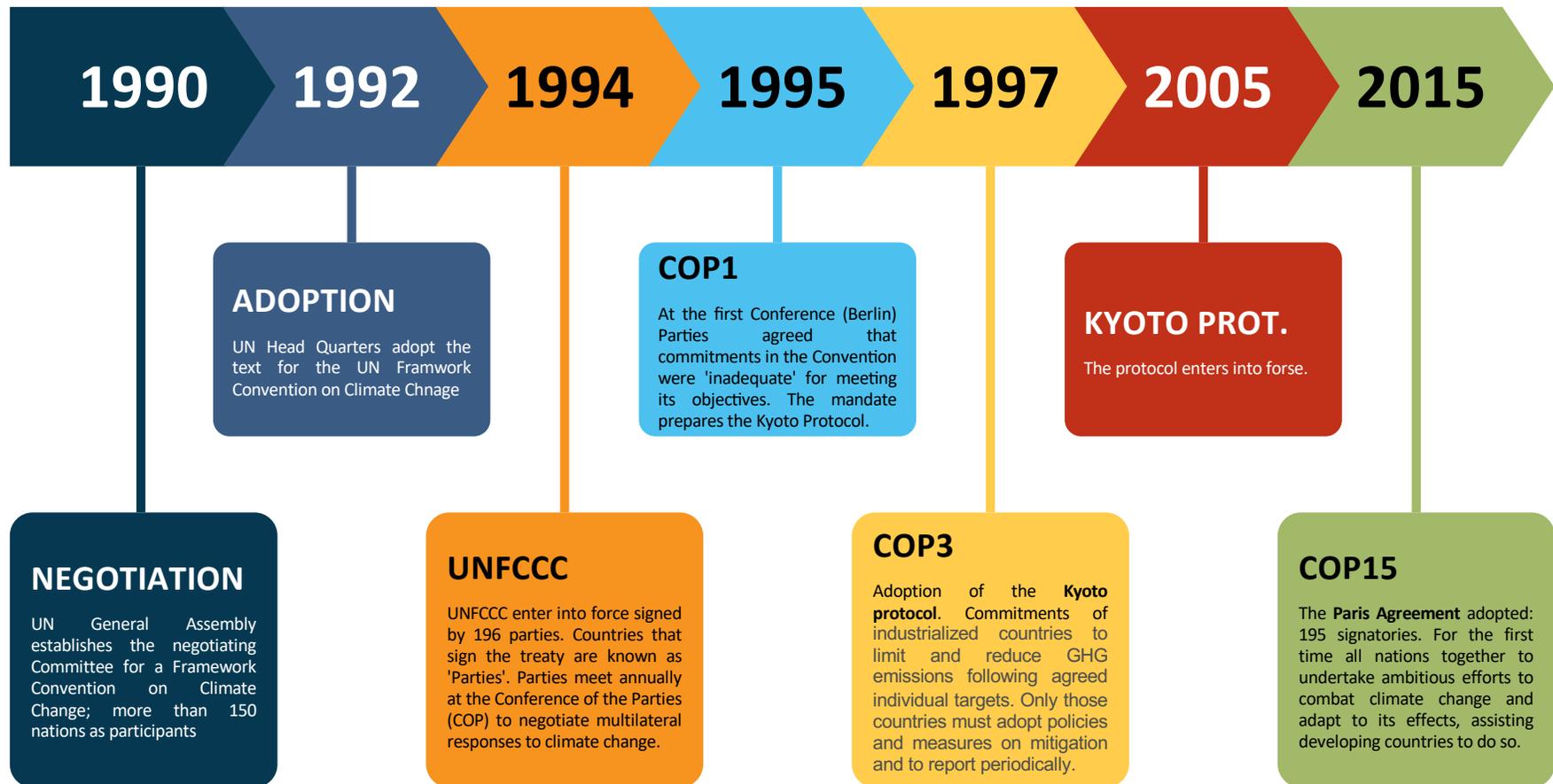
Extracts from her speech, 1989

IPCC (historical) findings



Developments

under UN Framework Convention on Climate Change



PARIS AGREEMENT

Temperature targets



Keeping warming **well below 2 °C** above pre-industrial levels
Aiming to limit the increase **to 1.5 °C**

Emission reduction targets



Aiming for global GHG emissions **to peak** as soon as possible
From 2050: aiming to achieve a **balance** between emissions and removals

Review mechanism



A review every **5 years** starting in 2023
Track progress towards NDC by a robust **transparency** and accountability system

IPCC (historical) findings

Temperatures increased by **0.3-0.6 C** over the last century; human emissions are **adding** to the natural GHG; the addition would be expected to result in **warming**

1

1990



European climate policy starts in 1990



Climate change was first discussed by the European Council in June 1990 urging the adoption as soon as possible of targets and strategies for limiting emissions of green house gases

Discussions



EU leaders agreed in October 1990 to stabilise GHG emissions of the European Community at 1990 levels by 2000

Agreement



Areas of energy (climate) policy were identified and addressed already in 1986:
 1) promoting renewable energy sources
 2) improving energy efficiency

Policy areas



A monitoring mechanism established with Decision 93/389/EEC, to assess development of national energy programmes including reduction of CO₂ and other GHG and monitor progress on the 2000 target

Monitoring

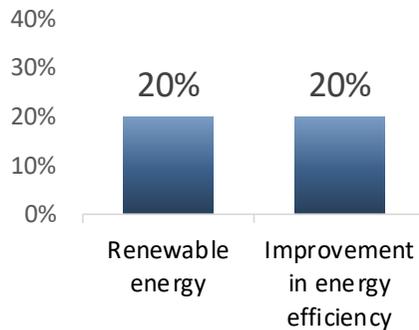
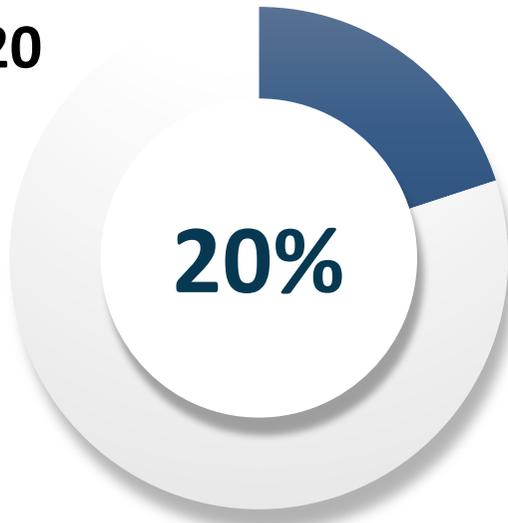


Climate-energy targets in EU

pre EU Green Deal

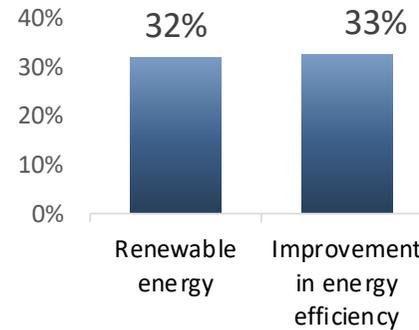
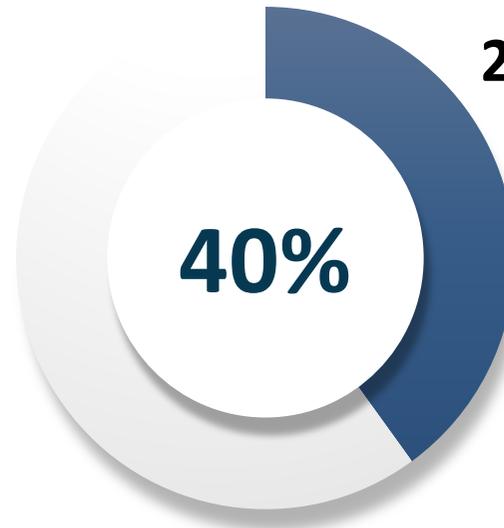
GHG CUTS VS 1990

2020



2020 Climate and Energy Package, 2009

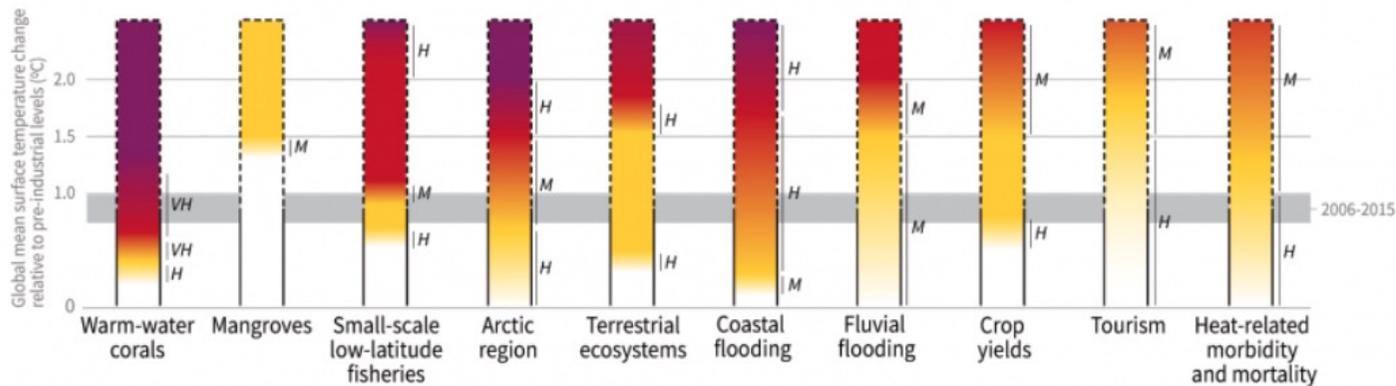
2030



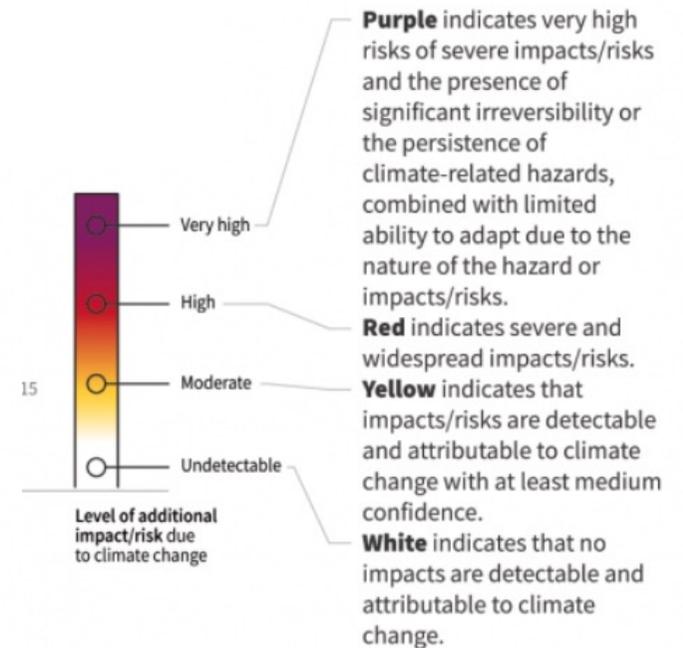
2030 Climate and Energy Package, 2014; 2018

2 °C not enough to avoid dramatic impacts

Impacts and risks for selected natural, managed and human systems



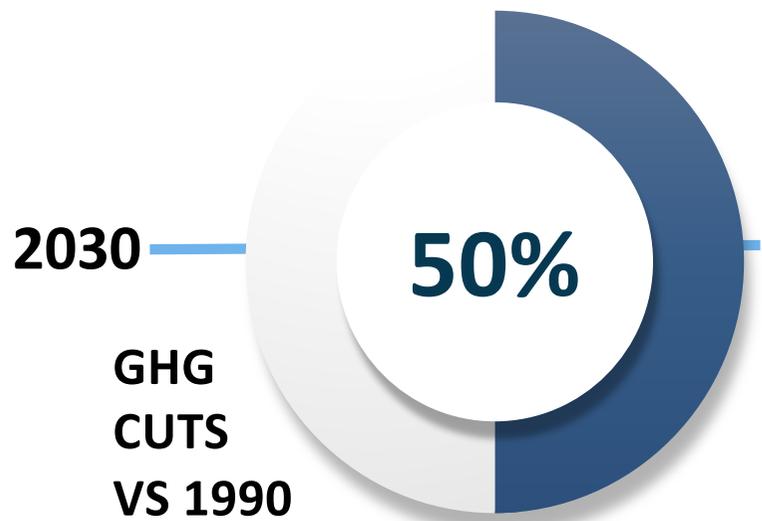
Confidence level for transition: L=Low, M=Medium, H=High and VH=Very high





Climate-energy in EU

Short (2030) and long-term (2050) targets



The European Green Deal, 2019

2050 Climate neutrality



Climate-energy in EU

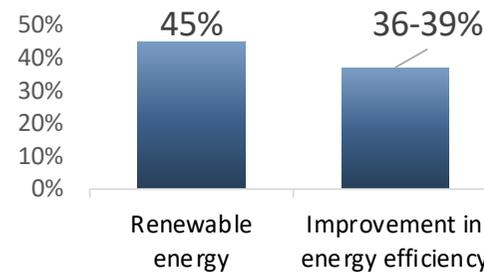
Short (2030) and long-term (2050) targets



The European Green Deal, 2019

EU Climate Law, 2020

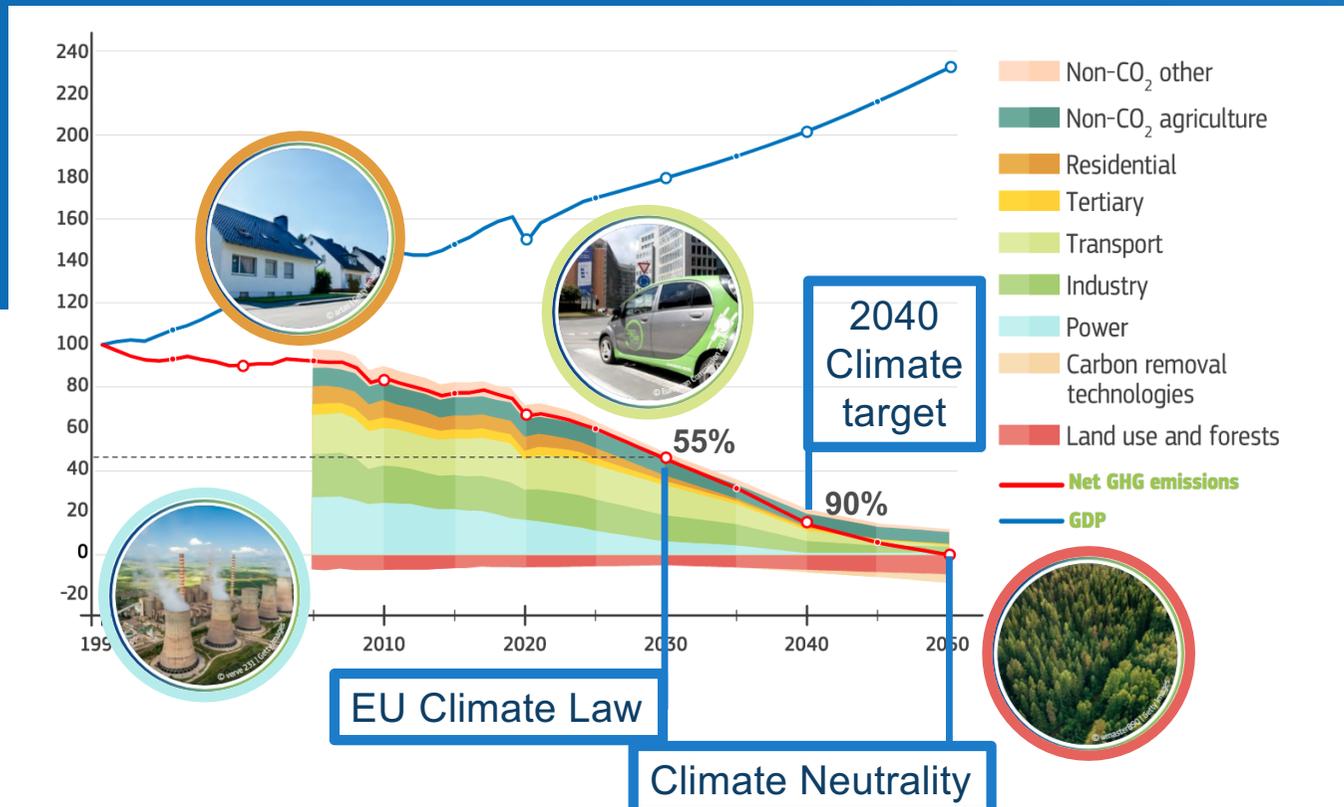
2050 **Climate neutrality**



Fit for 55, 2021; RePowerEU, 2022



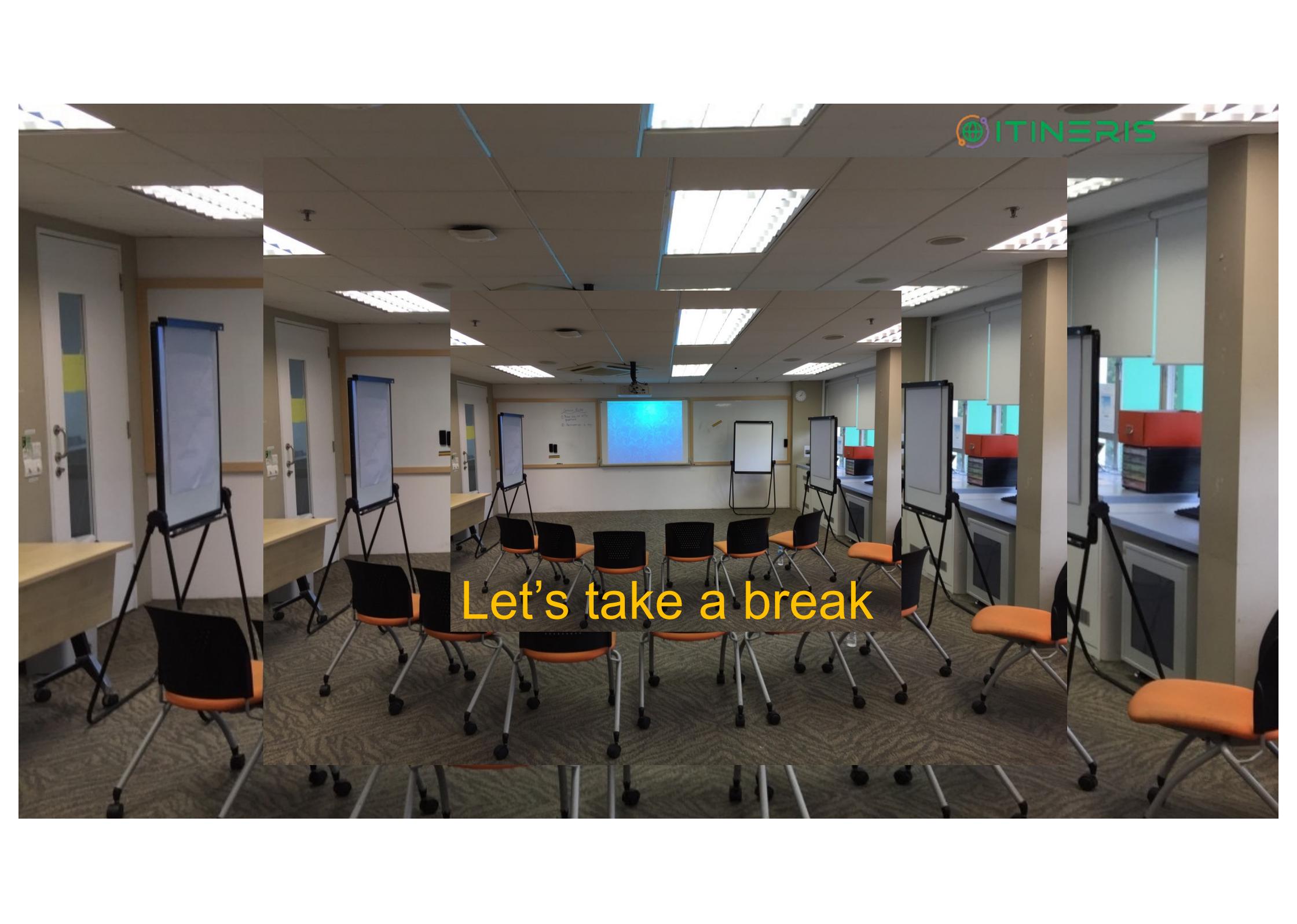
The EU path to climate neutrality



Adapted from https://eur-lex.europa.eu/resource.html?uri=cellar:749e04bb-f8c5-11ea-991b-01aa75ed71a1.0001.02/DOC_1&format=PDF

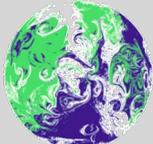
Questions?



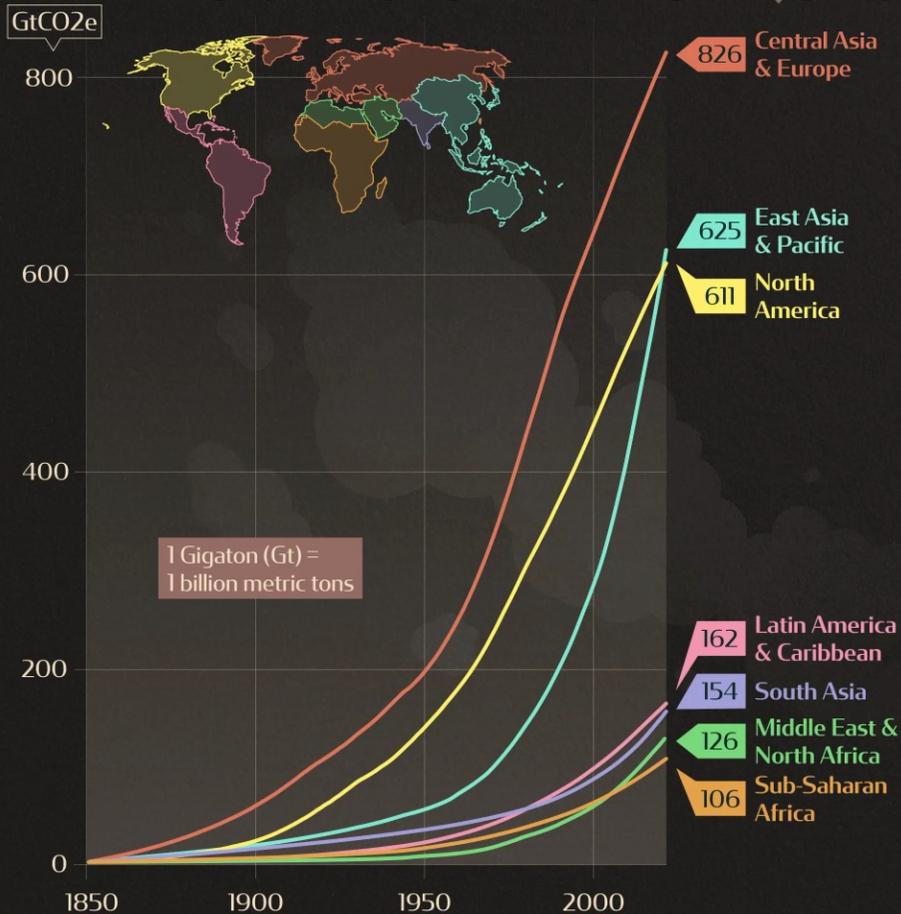
A wide-angle photograph of a modern conference room. The room is carpeted with a grey and brown pattern. In the center, there is a circle of black office chairs with orange seats. Several flipcharts on stands are positioned around the room. In the background, there is a whiteboard and a large screen displaying a blue abstract image. The room has a drop ceiling with recessed lighting and a door on the left side.

Let's take a break

From Paris to Glasgow to Baku

 <p>COP26 - Glasgow</p> <p>Agreement addressing coal, with a call to “<u>phase down</u>” unabated coal power</p> <p>Development of the carbon market mechanism</p> <p>Provisions for <u>losses and damages</u></p> <p><u>Global Methane Pledge</u>, signed by over 100 countries, aimed to reduce global methane emissions by 30% by 2030</p> <p>2021</p>	 <p>COP27 – Sharm El-Sheikh</p> <p>Establishment of a <u>specific fund for losses and damages</u></p> <p>Maintain a clear intention to <u>keep 1.5°C</u> within reach, though concerns remain over insufficient progress on emissions reductions</p> <p>Mobilise <u>greater financial support</u> for developing countries</p> <p>2022</p>	 <p>COP28 - Dubai</p> <p>First major international commitment to “<u>transition away from fossil fuels</u>”, though specific timelines for a complete phase-out remained undefined</p> <p>Established <u>time-bound targets</u> under the Global Goal on Adaptation</p> <p>Need for political leadership to keep the 1.5°C goal alive</p> <p>2023</p>	 <p>COP29 - Baku</p> <p>Tripled <u>climate finance</u>, and countries will work to mobilize more</p> <p>Help <u>finance protections</u> for those on the frontlines, especially the most vulnerable</p> <p>Reached global agreement on <u>carbon markets</u></p> <p>2024</p>
--	---	--	---

Cumulative GHG emissions by region

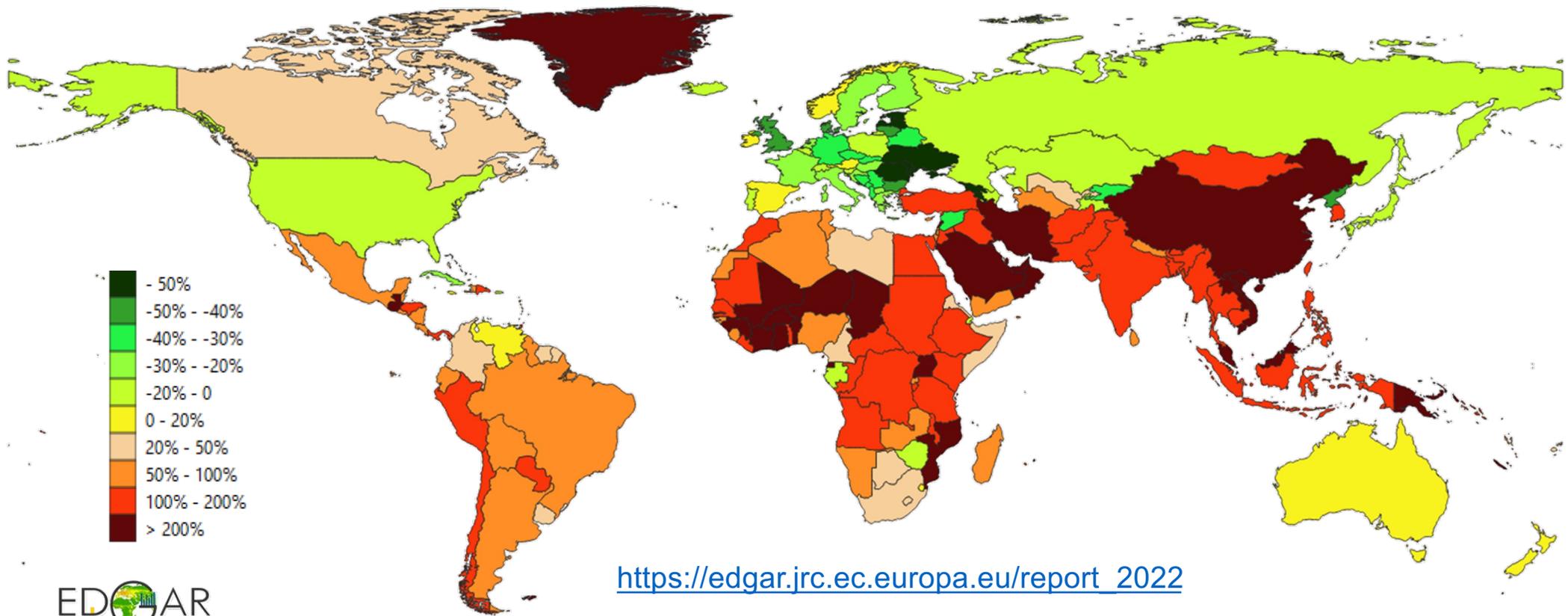


79% total GHG since 1850

Their uptrend coincides with heavy industrialization and increasing levels of consumption

Based on the Kyoto Protocol categories of greenhouse gas (GHG) emissions: CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆. Excludes Land Use Change and Forestry. Source: Climate Watch - PIK (2024).

GHG emission changes from 1990 to 2021



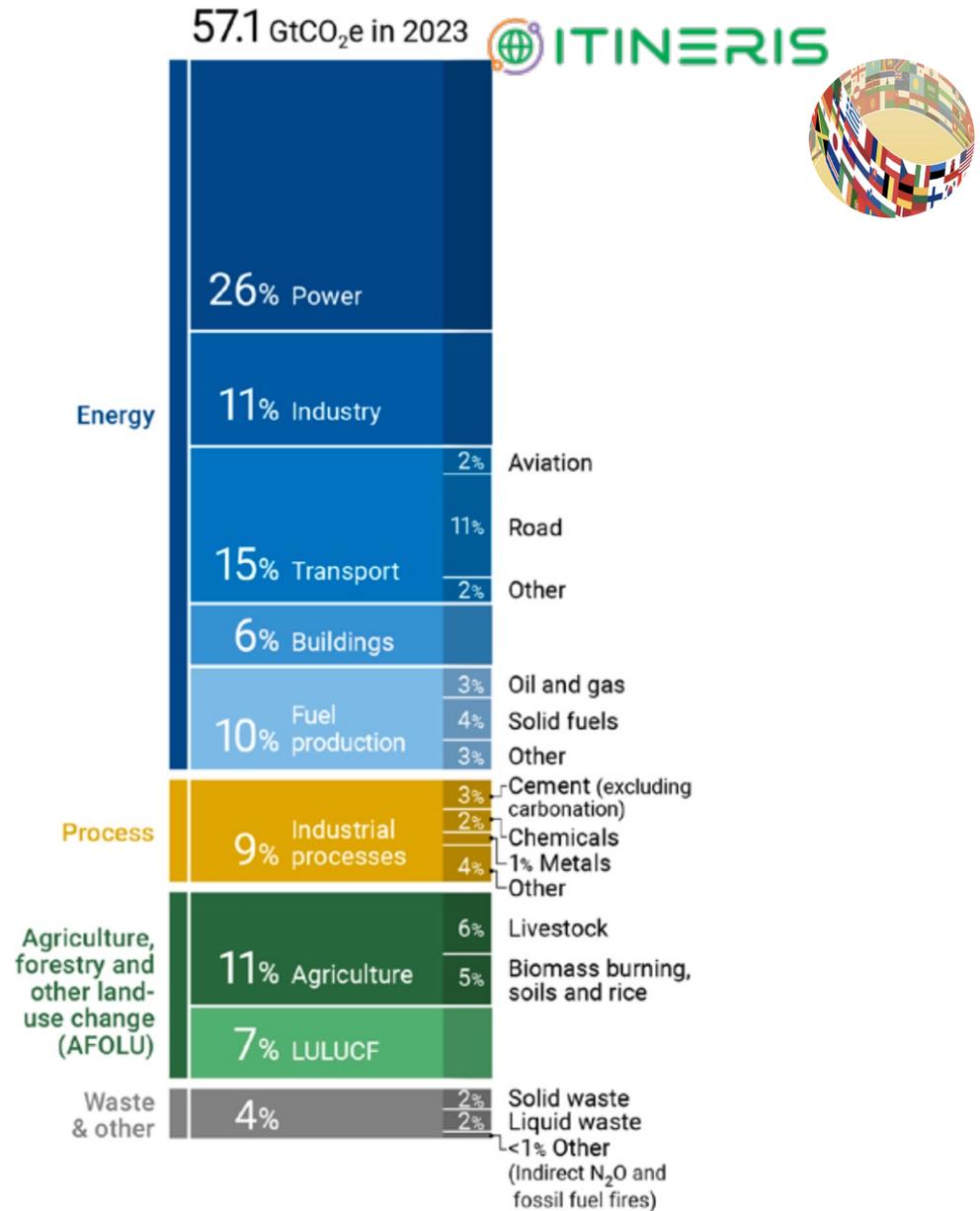
https://edgar.jrc.ec.europa.eu/report_2022

https://edgar.jrc.ec.europa.eu/dataset_ghg70

Major sectors of GHG emissions

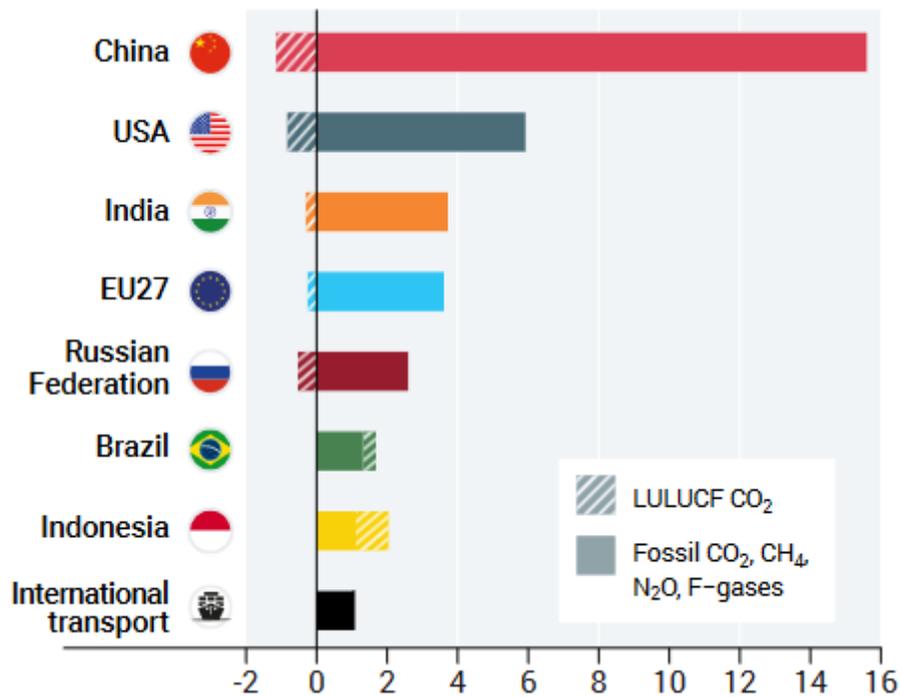
Global greenhouse gas emissions set a new record in 2023, a 1.3% increase from 2022 levels

UNEP Emissions Gap Report 2024: No more hot air ... please!





Major emitters of GHG

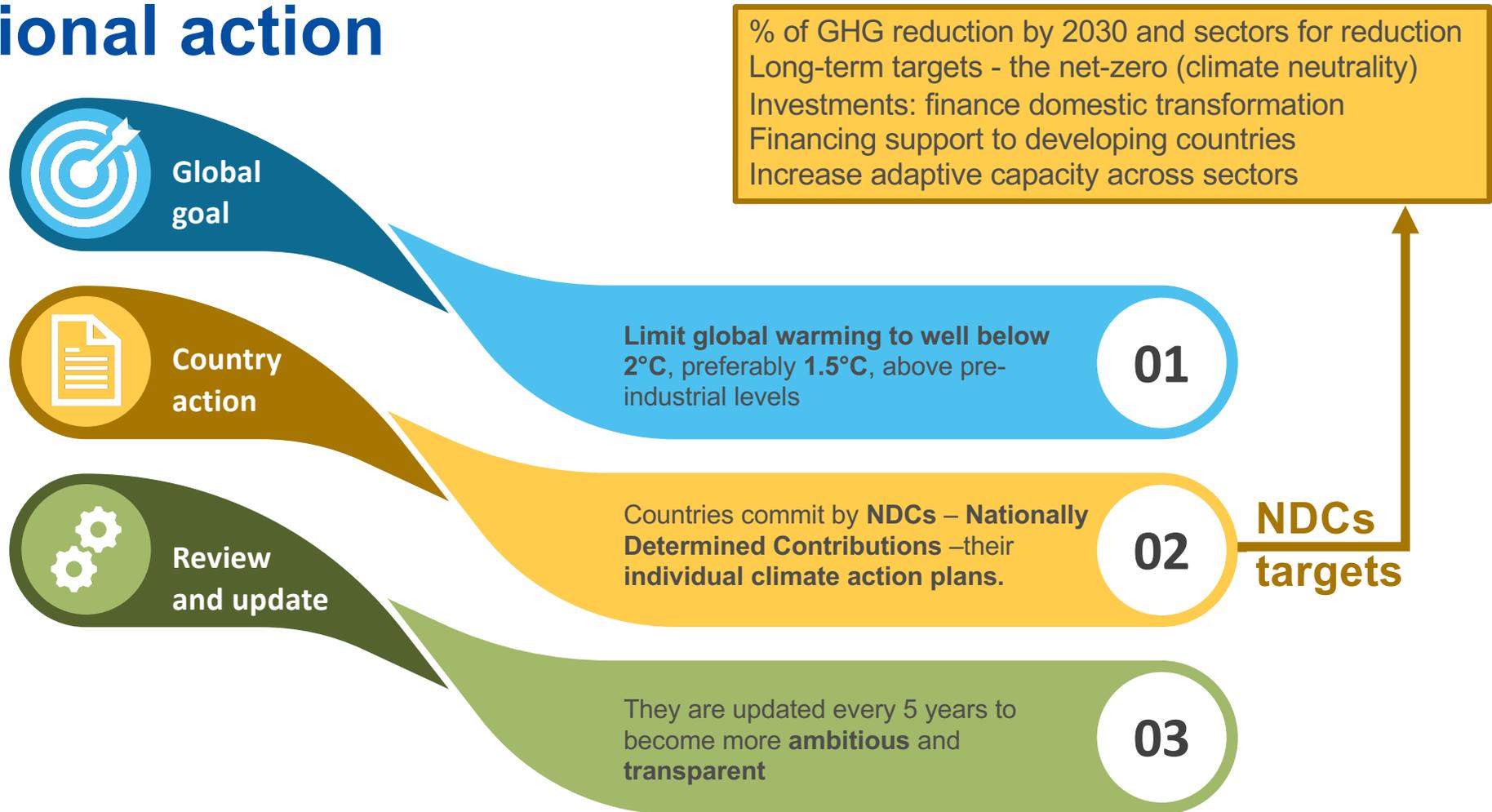


Per capita emissions (tCO₂e)

	19
	18
	11
	7.3
	6.0
	2.9

UNEP Emissions Gap Report 2023: Broken Record

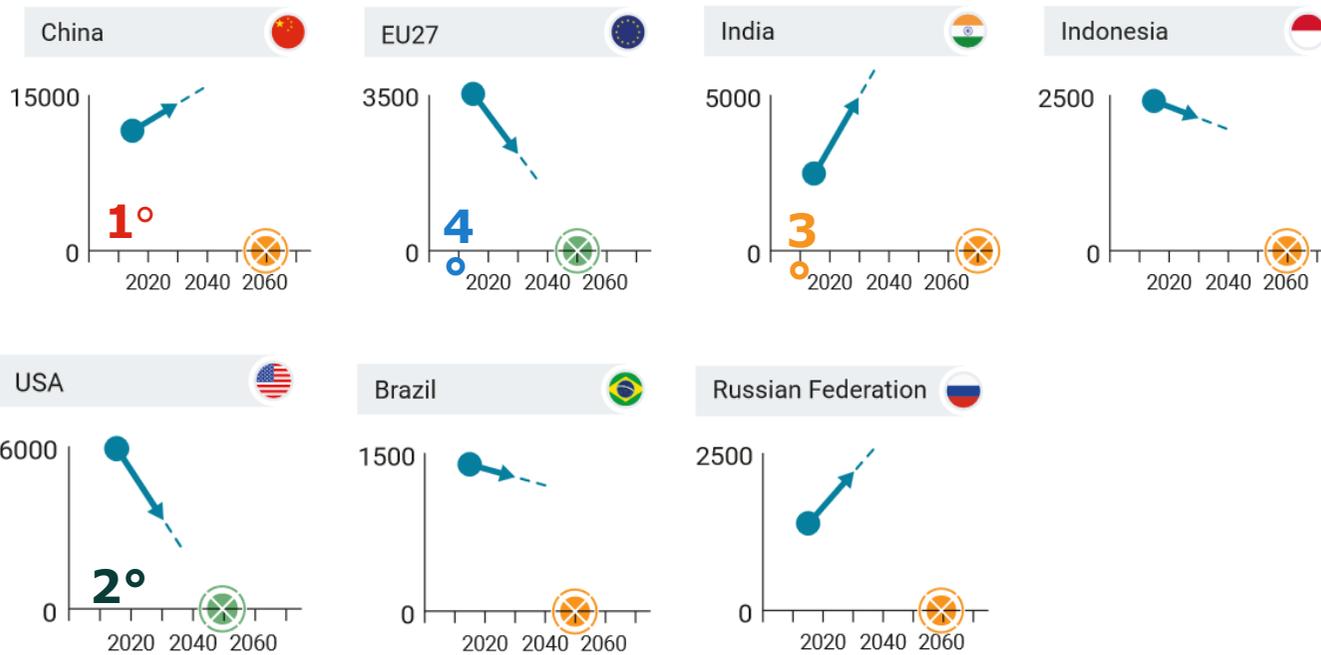
Paris agreement: turning global goals into national action





Emission trajectories of major emitters

towards climate neutrality



Countries are still off track to deliver on the globally insufficient mitigation pledges for 2030

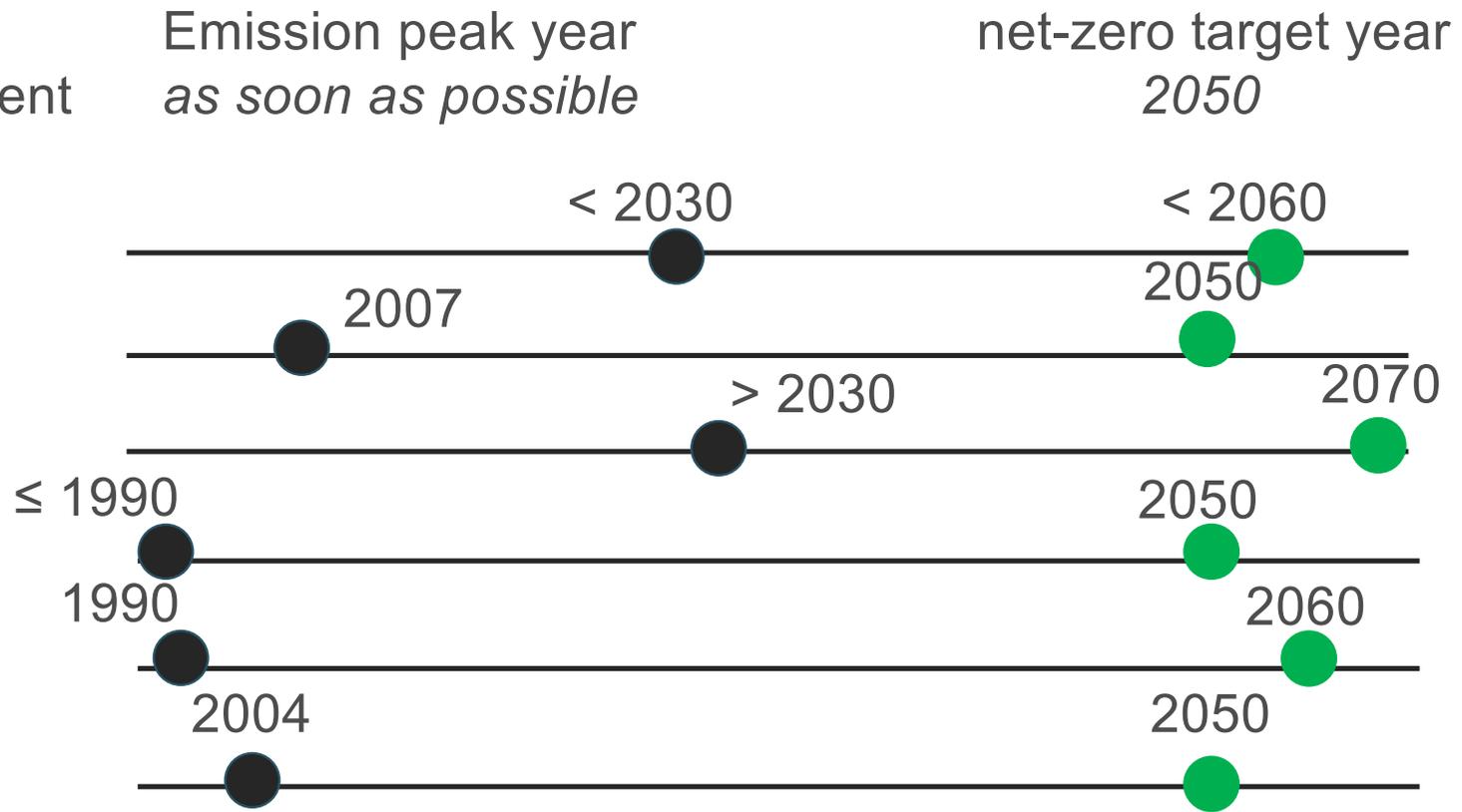
- Net-zero GHG targets
- Net-zero with unclear or CO₂-only coverage

UNEP Emissions Gap Report 2022

From peak to zero: where countries stand on the climate path

UNEP Emissions Gap Report 2024:
No more hot air ... please!

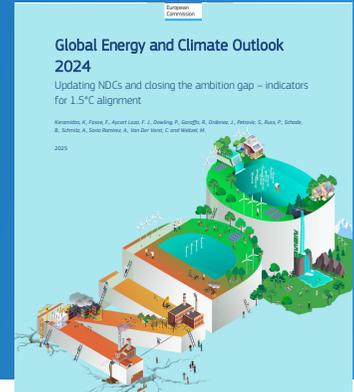
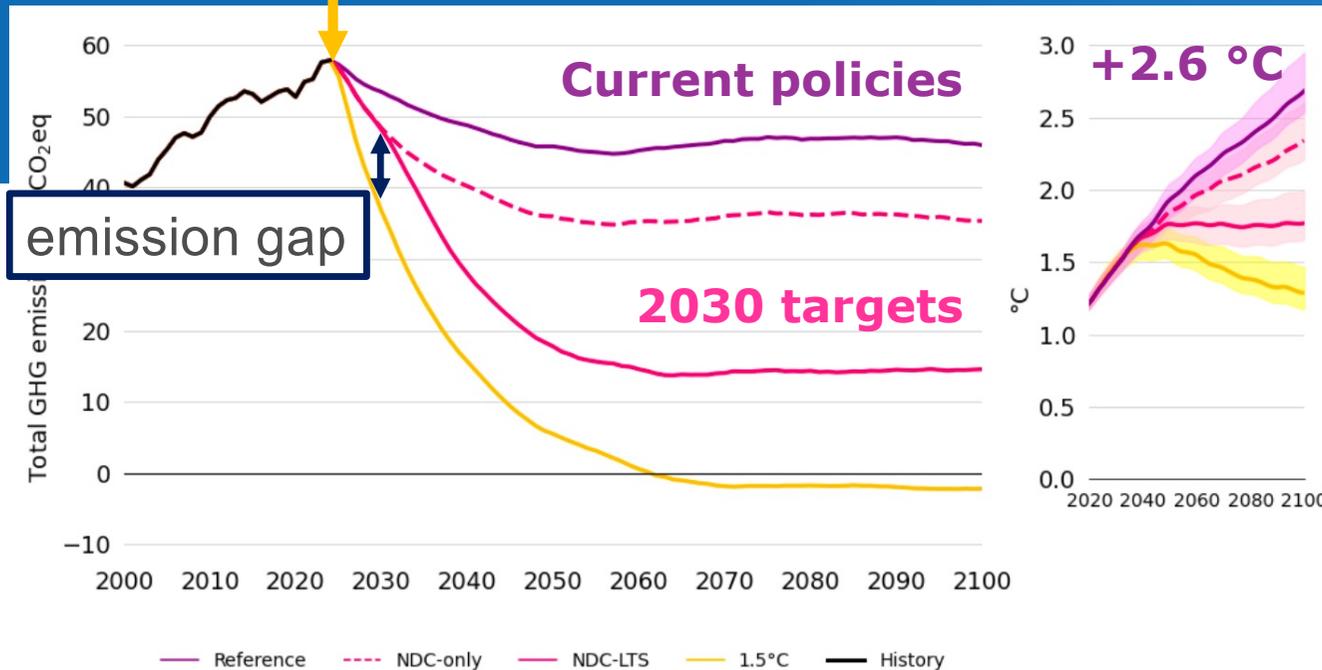
Paris agreement
(2015)





Bridging the gap: can current efforts meet the 1.5°C goal?

emission peak



NDC: National Determined Contributions

NDC-LTS: NDC and Long Term Climate Strategies

**JRC Global Energy and Climate Outlook 2024:
Updating NDCs and closing the ambition gap, 2025**



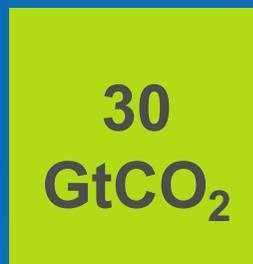
The climate countdown

emissions and the shrinking carbon budget

Carbon budget:
total amount of
carbon emissions
that can be emitted
for temperatures to
stay below 1.5 C



50% likelihood



83% likelihood



**total emissions
in 2023**

Climate Change Tracker



The climate countdown

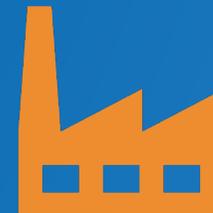
emissions and the shrinking carbon budget



50% likelihood



83% likelihood



57.1
GtCO₂

Carbon budget
for 2 C

total emissions
in 2023

How close are we to the climate red line?

Remaining carbon budget		
for temperature C	Likelihood %	exhausted in
1.5	50	2028
	83	2025
2	50	2051
	83	2042

High-impact solutions

emissions cuts within reach by 2030

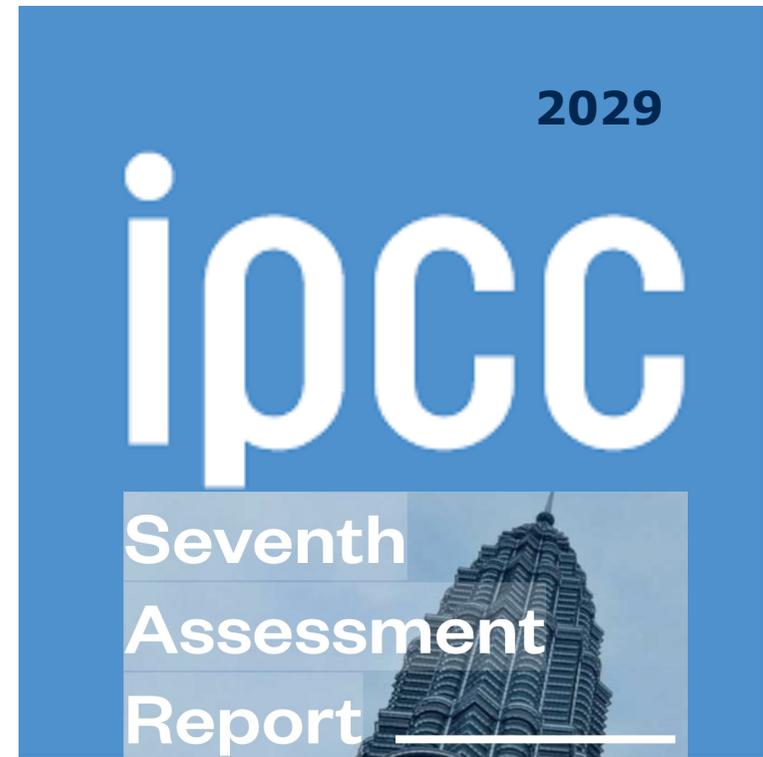
Annual quantity of GHG reductions or removals that can be achieved: 31 GtCO₂

Energy 12.2 GtCO ₂	AFOLU 8 GtCO ₂	Industry 4.4 GtCO ₂	Building 3.2 GtCO ₂	Transport 3.2 GtCO ₂
<ul style="list-style-type: none"> • Solar energy • Wind energy • Hydropower • Nuclear power • Geothermal power • Reduced CH₄ emissions from production • 	<ul style="list-style-type: none"> • Agriculture • Forestry • Reduced food waste • Diet change • ... 	<ul style="list-style-type: none"> • Energy efficiency • Material efficiency • Recycling • 	<ul style="list-style-type: none"> • New buildings • retrofitting • Appliances • 	<ul style="list-style-type: none"> • Modal shift • Electric vehicles • Shipping •

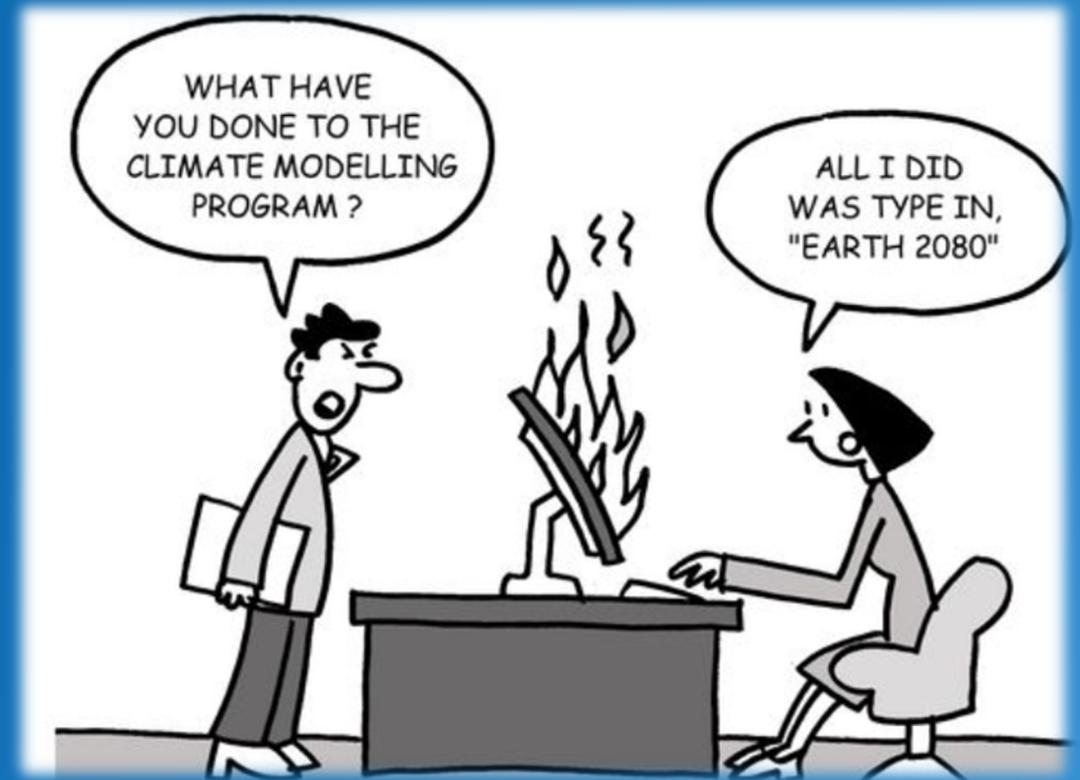
Enough to fill the emission gap to 1.5 C!

**UNEP Emissions Gap Report 2024:
No more hot air ... please!**

What's next? COP30 e IPCC AR7



- 🌡️ Necessity of a systemic transition across different sectors at the same time. What are the challenges in achieving this?
- 🌡️ What future directions should research take to better inform climate change policies?



Outline

The role of science in shaping climate policy:

1) From history to present

 **Historical evolution** of the science-policy interface on climate change

 **Milestones** leading to the **Paris Agreement (2015)**

 **Recent EU climate policies** and the European Green Deal

 **Global emission trends and mitigation potentials:** opportunities, barriers, and pathways forward

2) Scientific methods to provide information to policy

 What scientific questions would you ask to better understand a climate extreme event?



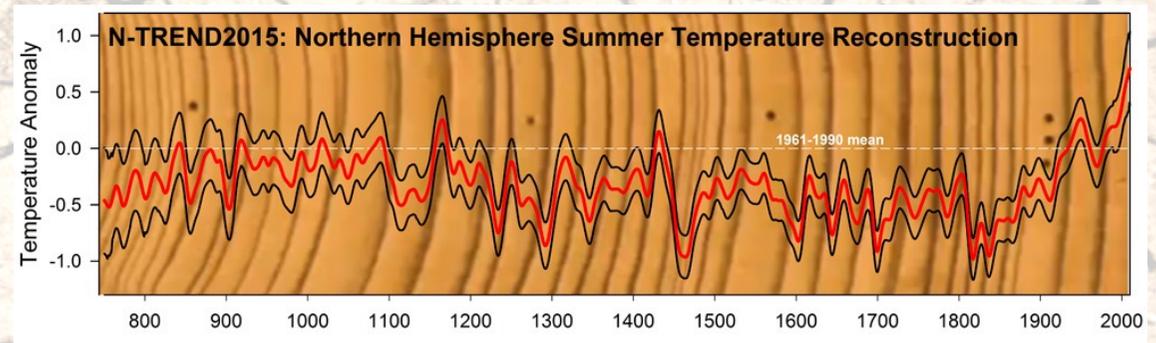
Assessing Climate Change



Paleoclimatology

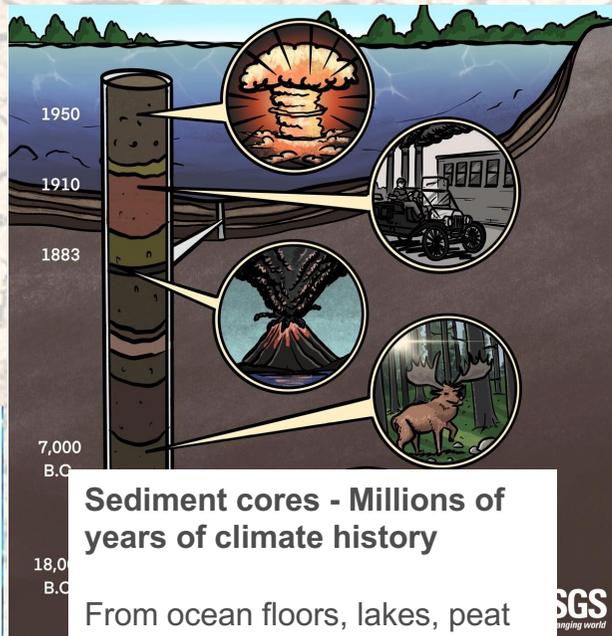
Ice cores; tree rings; sediment cores; pollen analysis; coral reefs; speleothems; historical data and proxies

Dendrochronology: using trees to study time



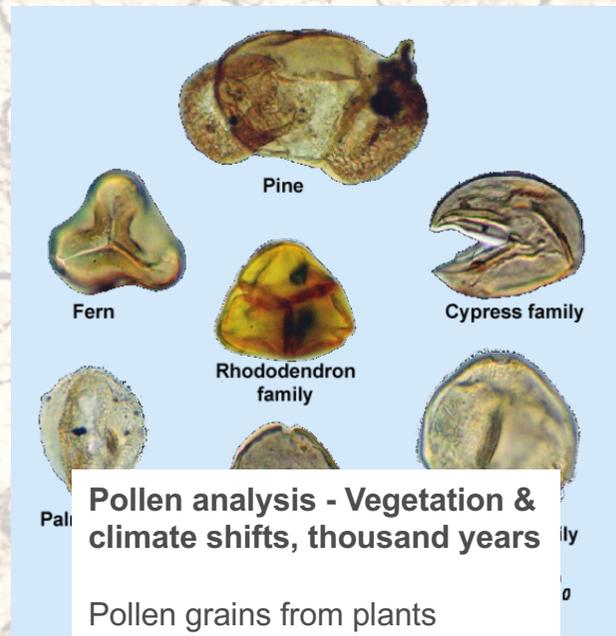
**National Oceanic and Atmospheric Administration, USA
and Columbia University**

Sediments, pollen, corals and records



Sediment cores - Millions of years of climate history

From ocean floors, lakes, peat bogs; through organic material, pollens, isotopes that indicate past climate



Pollen analysis - Vegetation & climate shifts, thousand years

Pollen grains from plants accumulate in sediments over time; reconstructing temperature and precipitation



Coral reefs - Detailed ocean temperature records

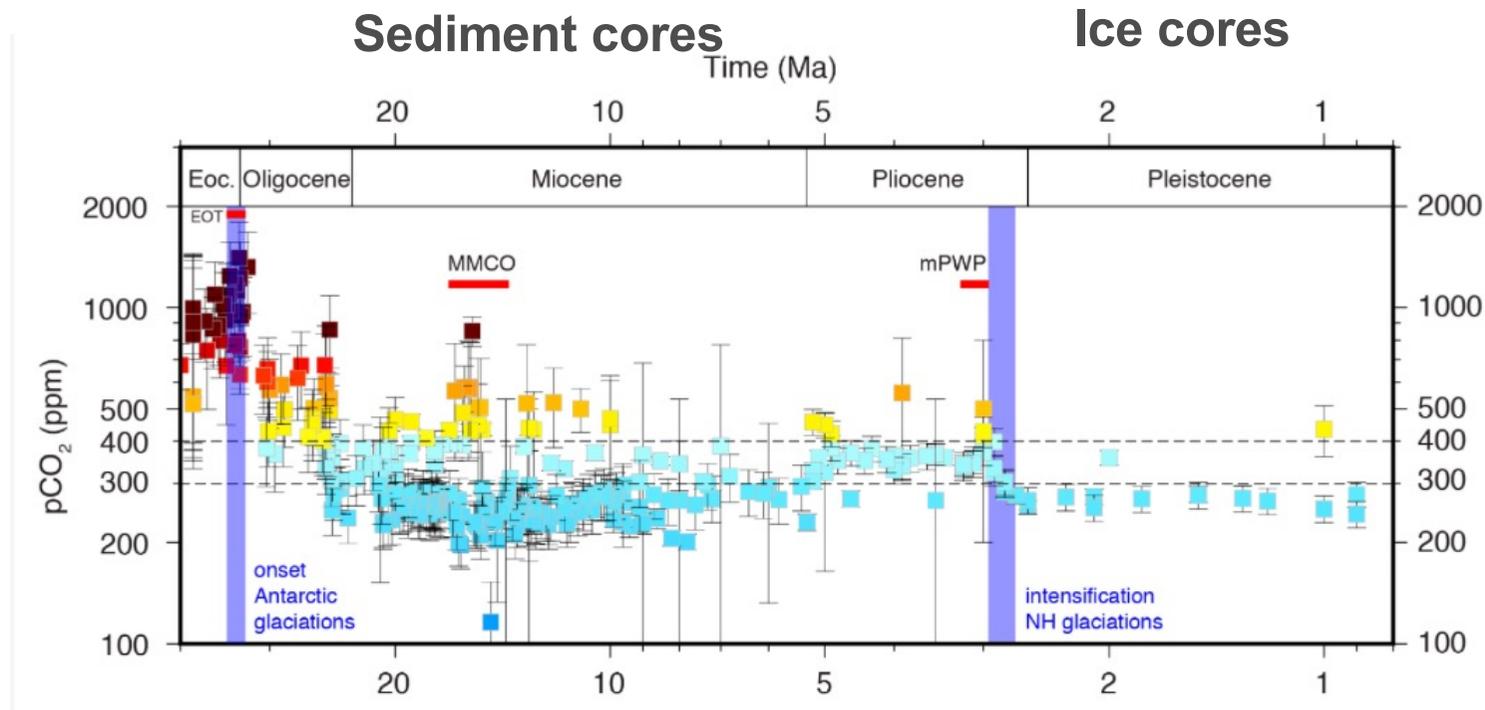
Corals build their skeletons using calcium carbonate, recording **ocean temperatures and salinity**, covering centuries

hour.	Mercur.
9-10 A.M.	81 1/2
7- P.M.	82
6. A.M.	78
9-10 A.M.	78
9. P.M.	74
5-30 A.M.	71 1/2
1-30 P.M.	76
8-10	74
6. A.M.	68
9.	72 1/2
1. P.M.	76
9.	73 1/2
6. A.M.	71 1/2
9.	72
9. P.M.	74

Historical Records & Proxy Data

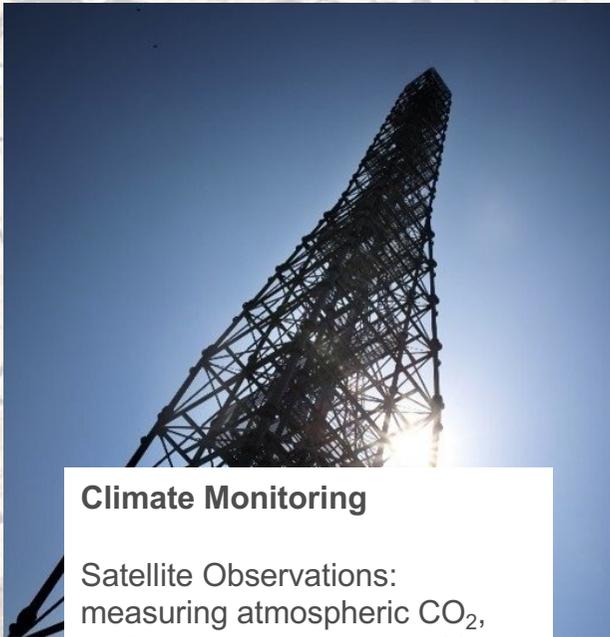
Ancient written accounts, paintings, and documents describe climate anomalies (e.g., Medieval Warm Period, Little Ice Age). Includes harvest records, river freezing dates, and extreme weather reports

Proxies reconstructing CO₂ concentrations



Bracegirdle et al., Geoscience, 2019

Monitoring: observing a changing planet from space and ground



Climate Monitoring

Satellite Observations: measuring atmospheric CO₂, surface temperatures, and ice cover; Ground Stations: weather stations, ocean buoys,...

Why?

- Detect long-term trends (e.g., global warming).
- Observe short-term changes (e.g., El Niño events).
- Validate climate models.
- Support policy and adaptation strategies.

Satellite observations – what and how



SURFACE TEMPERATURE

Infrared sensors
Trends: warming oceans, affecting marine ecosystems, storm development, and glacier melt
High spatial resolution—down to a few kilometers—allowing precise monitoring

ATMOSPHERIC CO₂

Spectrometers
CO₂ data by analyzing sunlight reflected off Earth's surface
Track emission hotspots, seasonal fluctuations, and evaluate national reporting under international agreements

CLOUD PROPERTIES RADIATION BALANCE

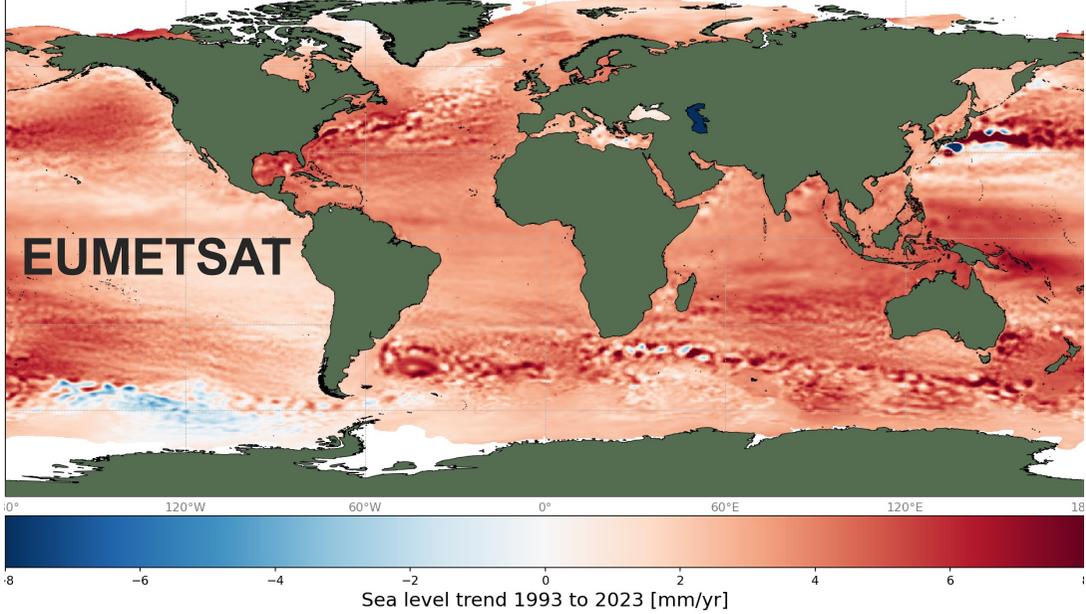
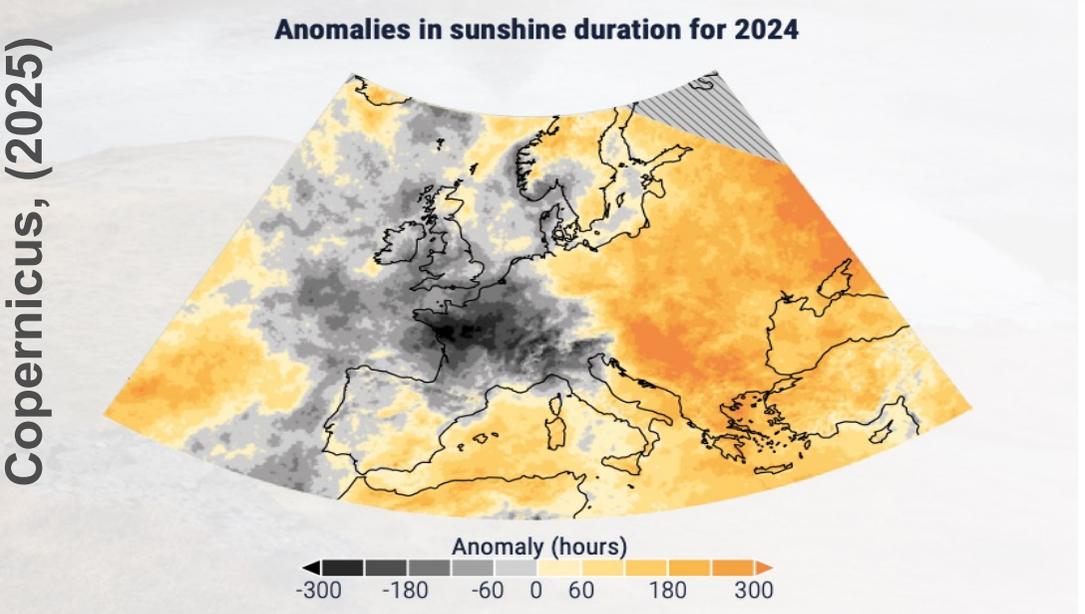
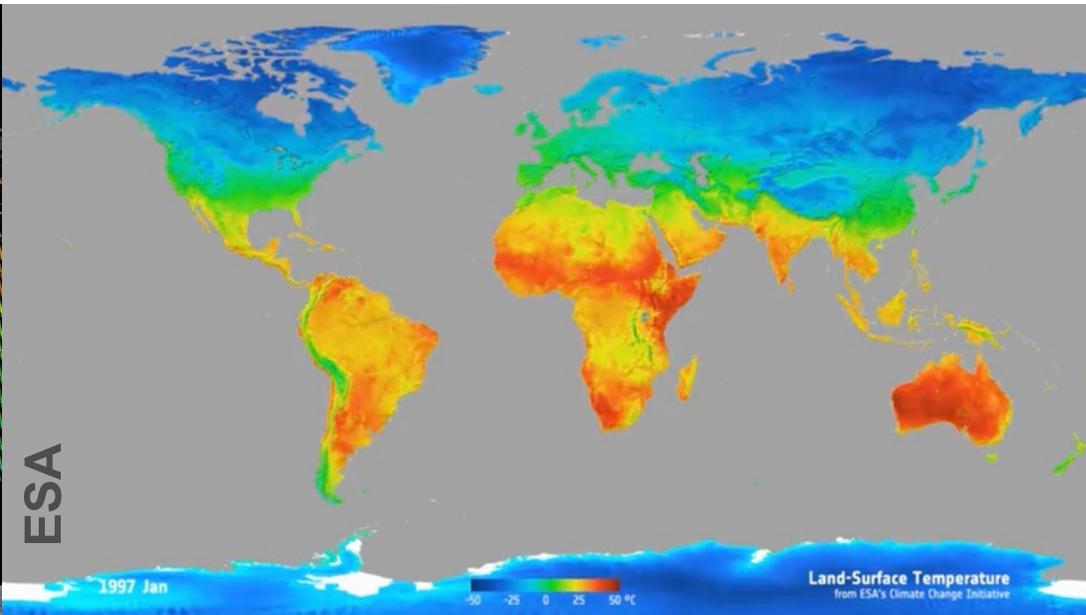
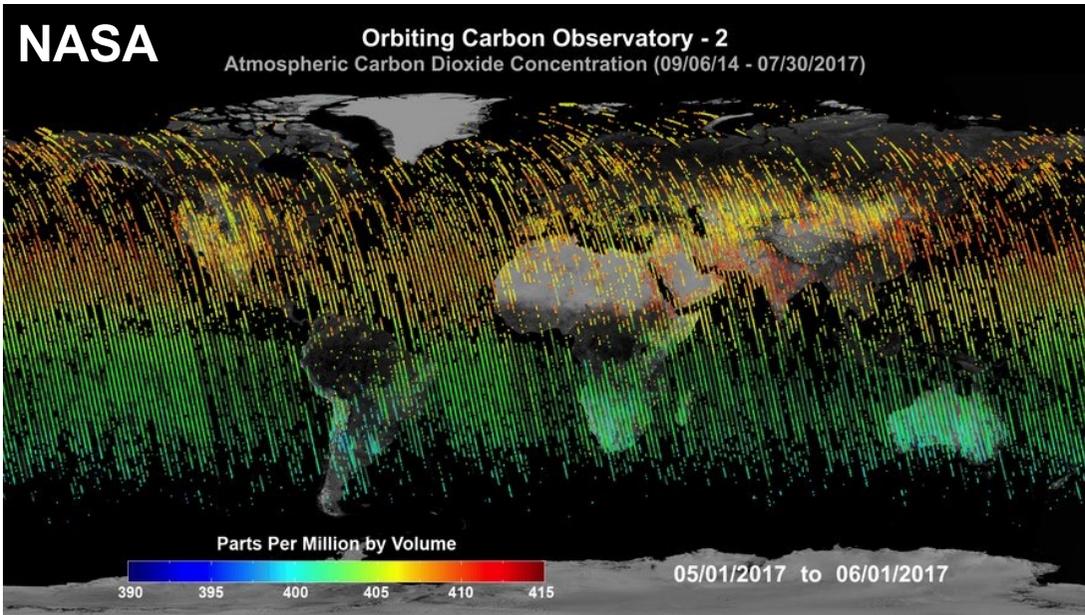
Observe cloud cover, height, and composition. Clouds reflect sunlight and trap infrared radiation. Measure incoming solar radiation, reflected light, and outgoing infrared radiation. Help determine Earth's energy balance

ICE COVER AND SNOW EXTENT

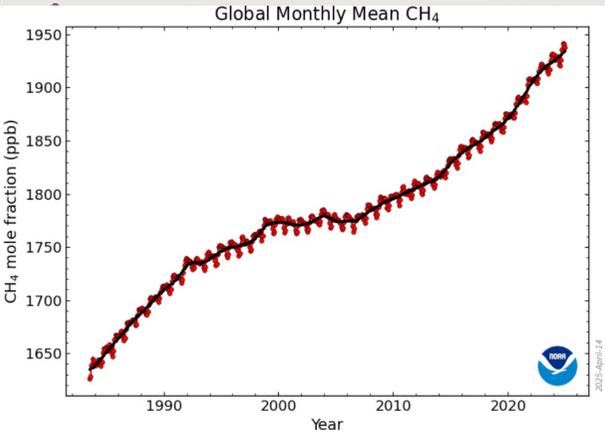
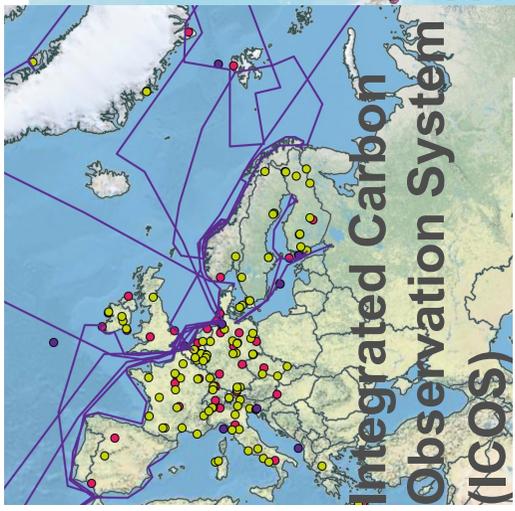
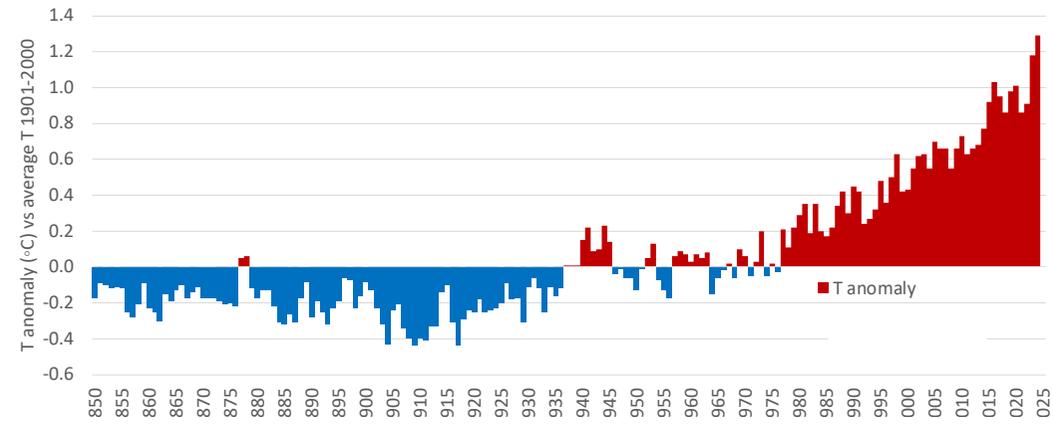
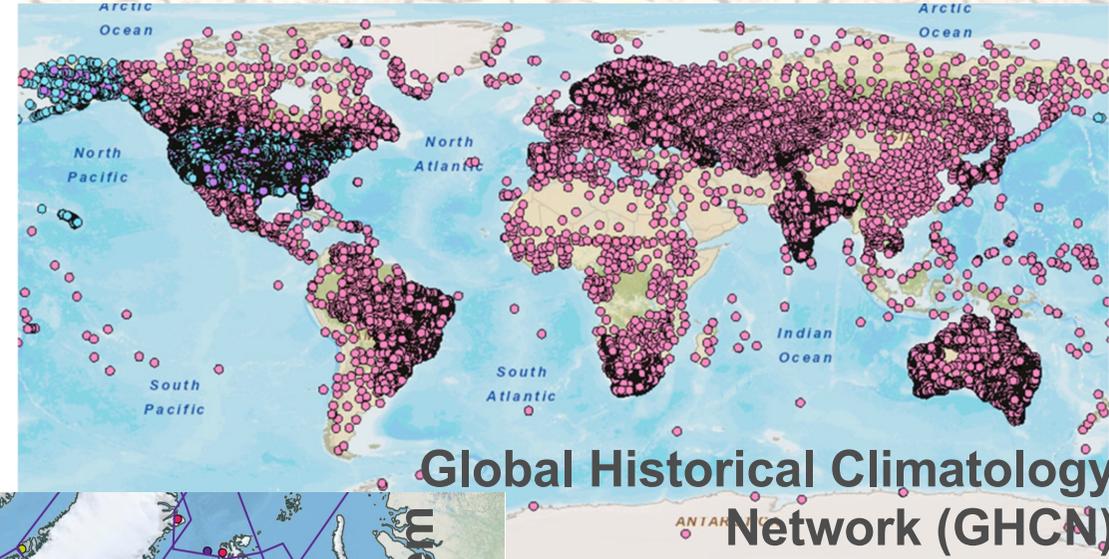
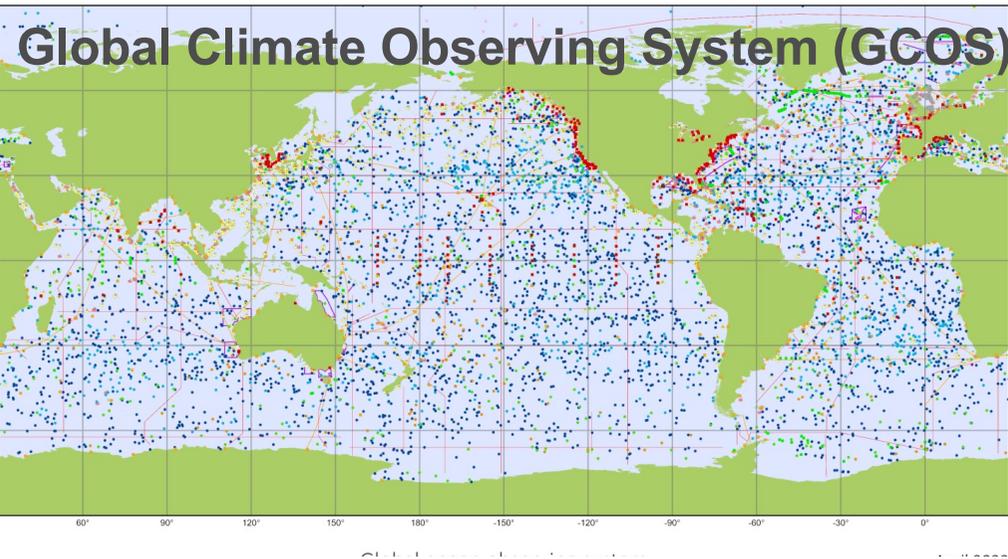
Lidar to measure the height of ice sheets, **passive microwave sensors** track sea ice extent and concentration. Vital not only for understanding climate feedbacks but also for projecting sea-level rise

SEA LEVEL AND OCEAN COLOUR

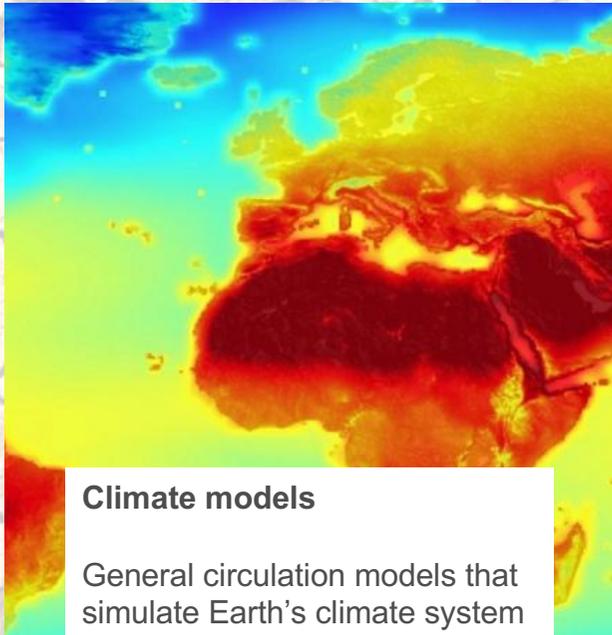
Radar altimeters to measure sea level. Detect ocean color to estimate phytoplankton levels (chlorophyll), primary productivity, and harmful algal blooms



Ground based data – essential complement



Simulating climate to assess it



Climate models

General circulation models that simulate Earth's climate system

Regional climate models providing finer resolution details

Definition

- mathematical representations of the Earth's climate system
- based on physical laws
- used to simulate past, present, and future climate conditions

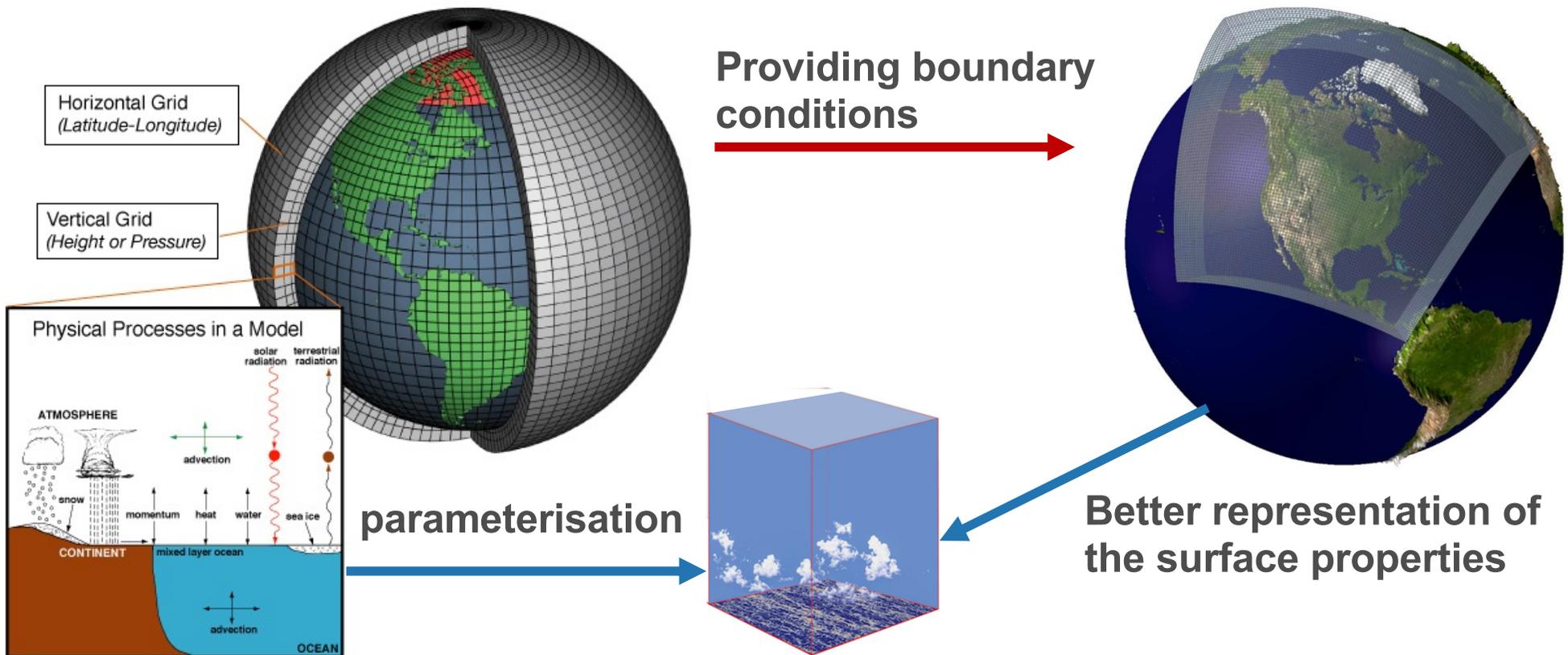
What are their components?

Component	What It Represents
Atmosphere	Air circulation, clouds, winds, heat exchange
Ocean	Heat transport, salinity, currents
Land Surface	Vegetation, soil moisture, snow cover
Cryosphere	Ice sheets, glaciers, sea ice
Carbon Cycle & Chemistry	CO ₂ uptake/release, methane, aerosols

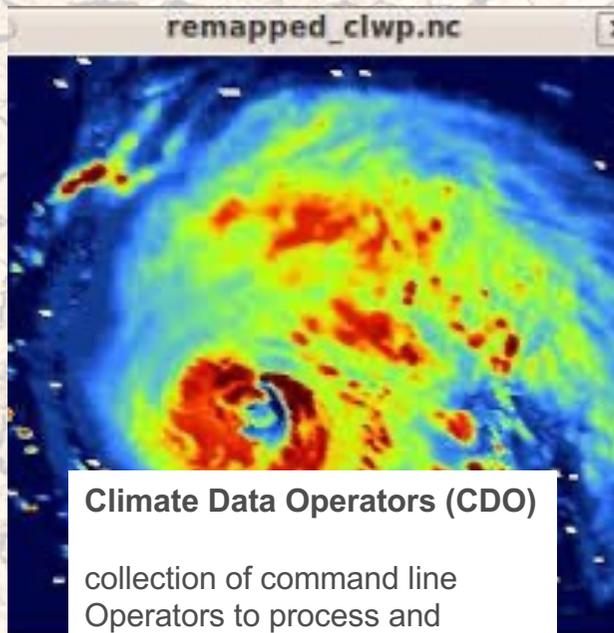
Global vs regional climate models

Global circulation models

Regional climate models



Tools for Climate Data Analysis



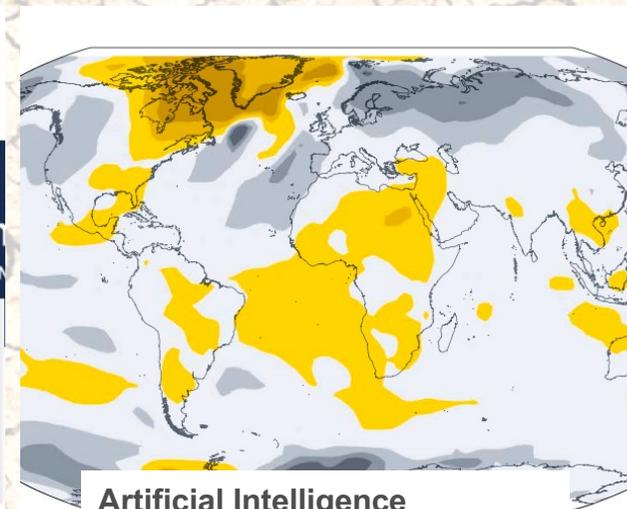
Climate Data Operators (CDO)

collection of command line Operators to process and analyse Climate model Data



Data Repositories

historical climate data and projections for research purposes (NOAA's NCEI and the European Copernicus Climate Change Service)



Artificial Intelligence

-0. machine-learning strategies to speed up climate modelling, reduce its energy costs and hopefully improve accuracy

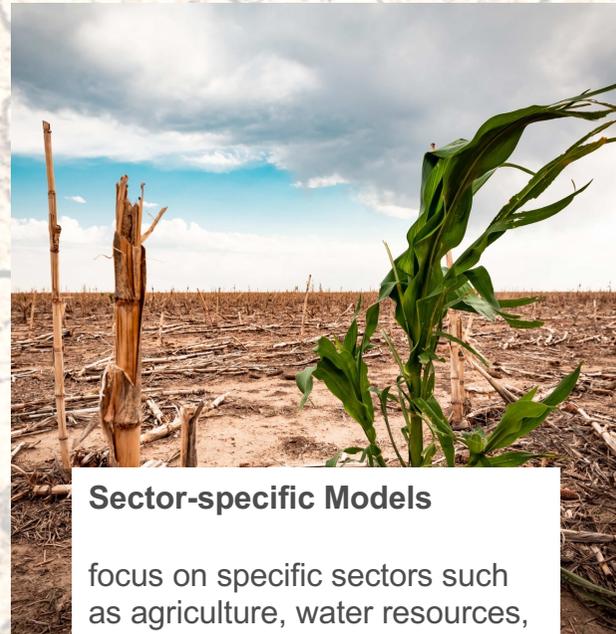
Assessing interactions and impacts



IMAGE

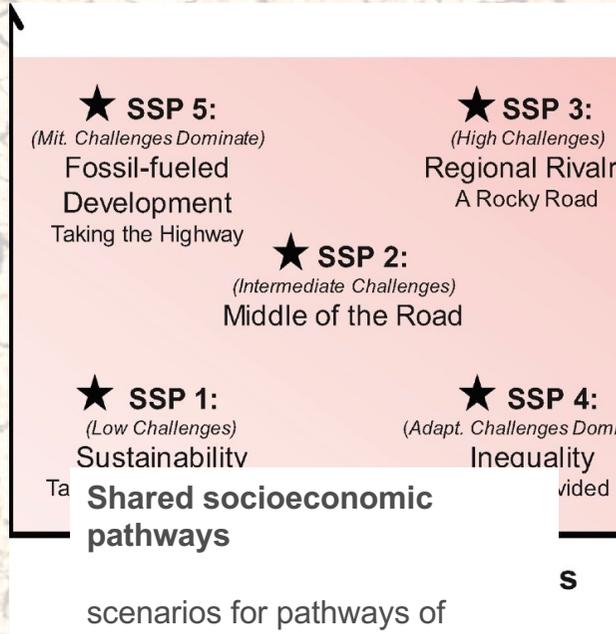
Integrated Assessment Model

assess the interactions between the economy, energy systems, land use, and climate; evaluate impacts of climate policies and explore pathways



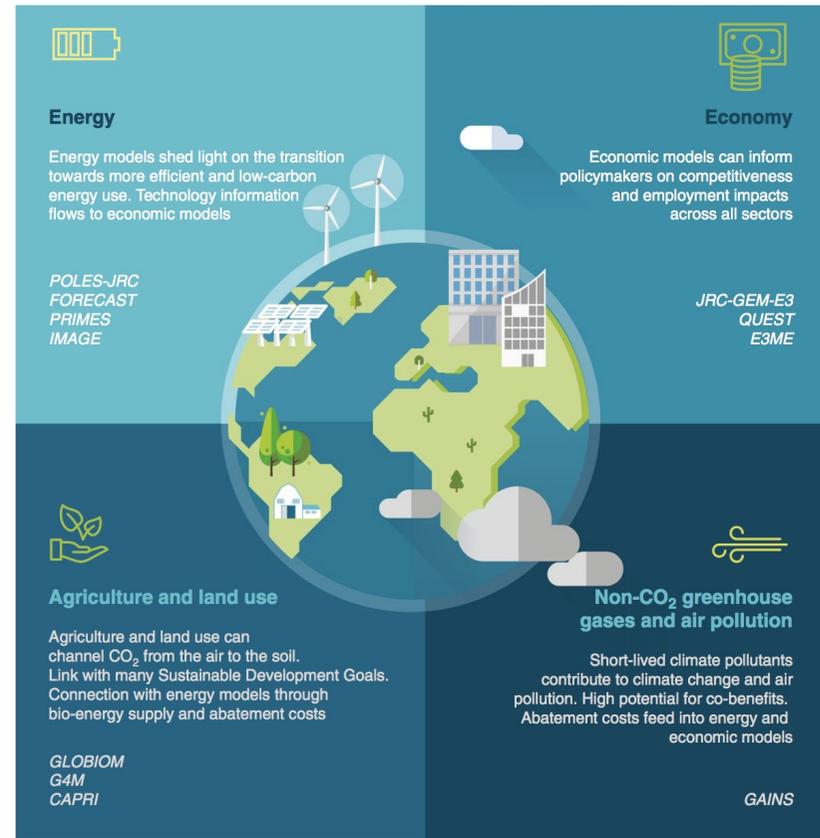
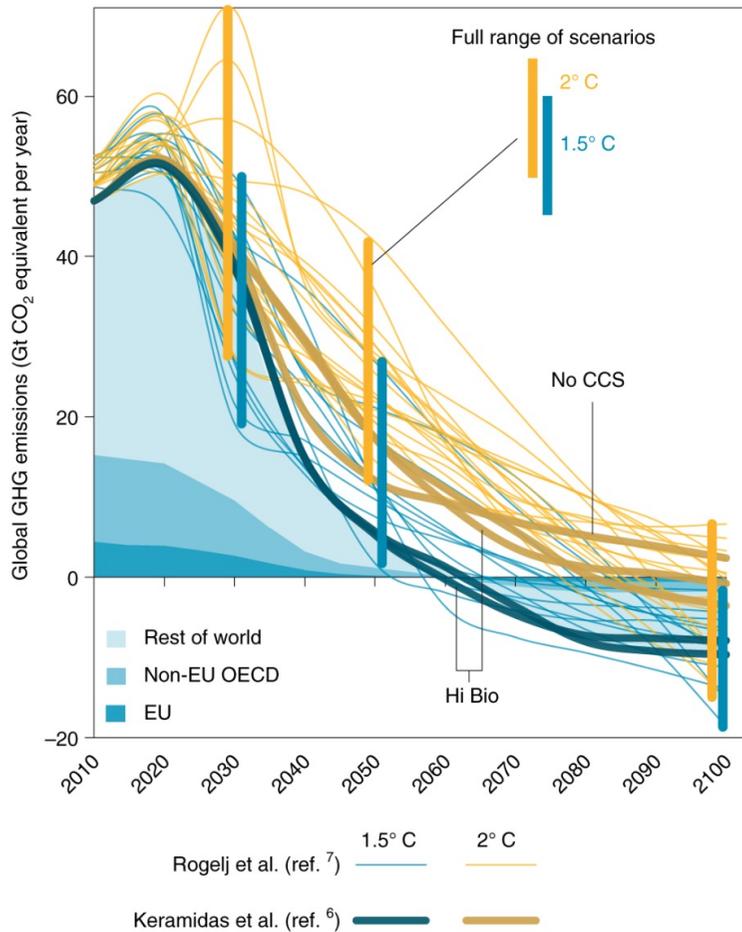
Sector-specific Models

focus on specific sectors such as agriculture, water resources, health, and biodiversity; assess impacts on specific systems, identify vulnerabilities, strategies

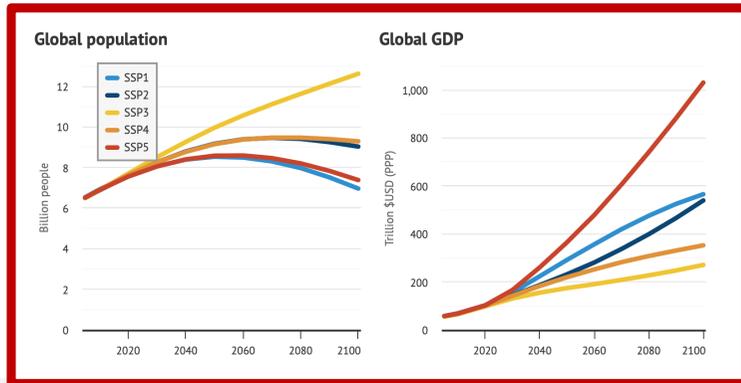


scenarios for pathways of socioeconomic development and their impacts on climate change

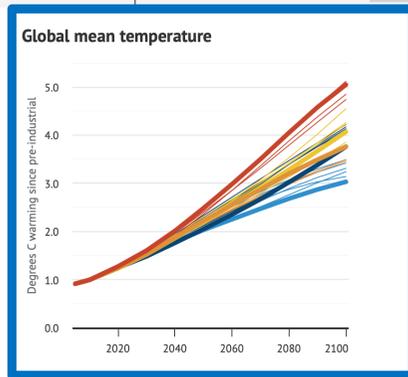
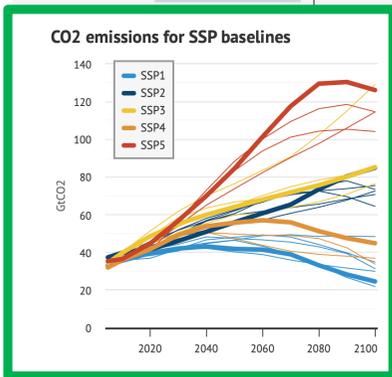
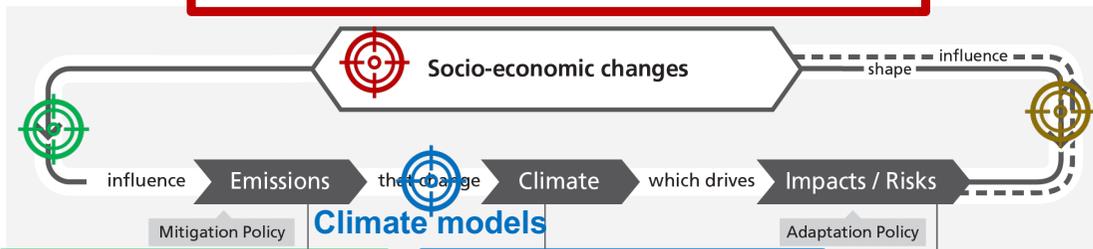
Robust science to prepare scenarios...



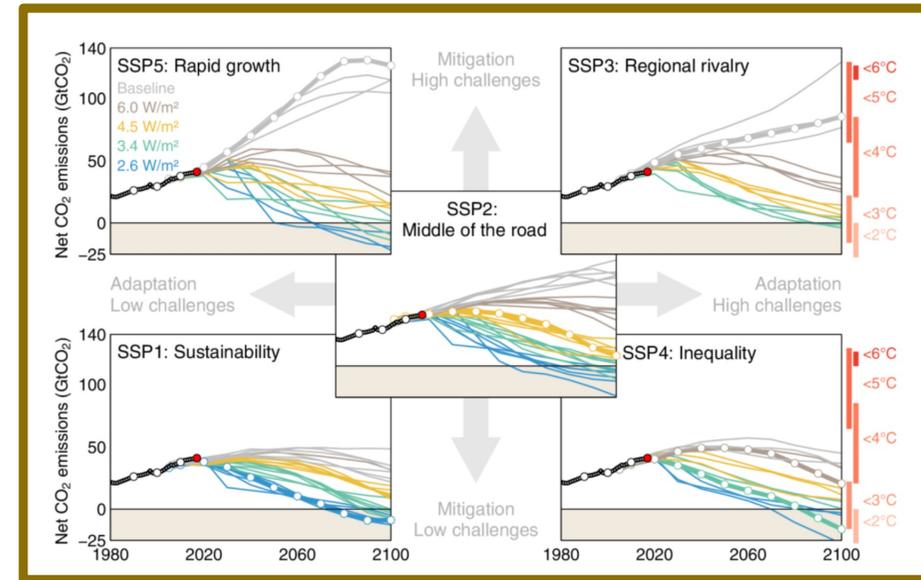
... policy makes the choice



Integrated assessment models



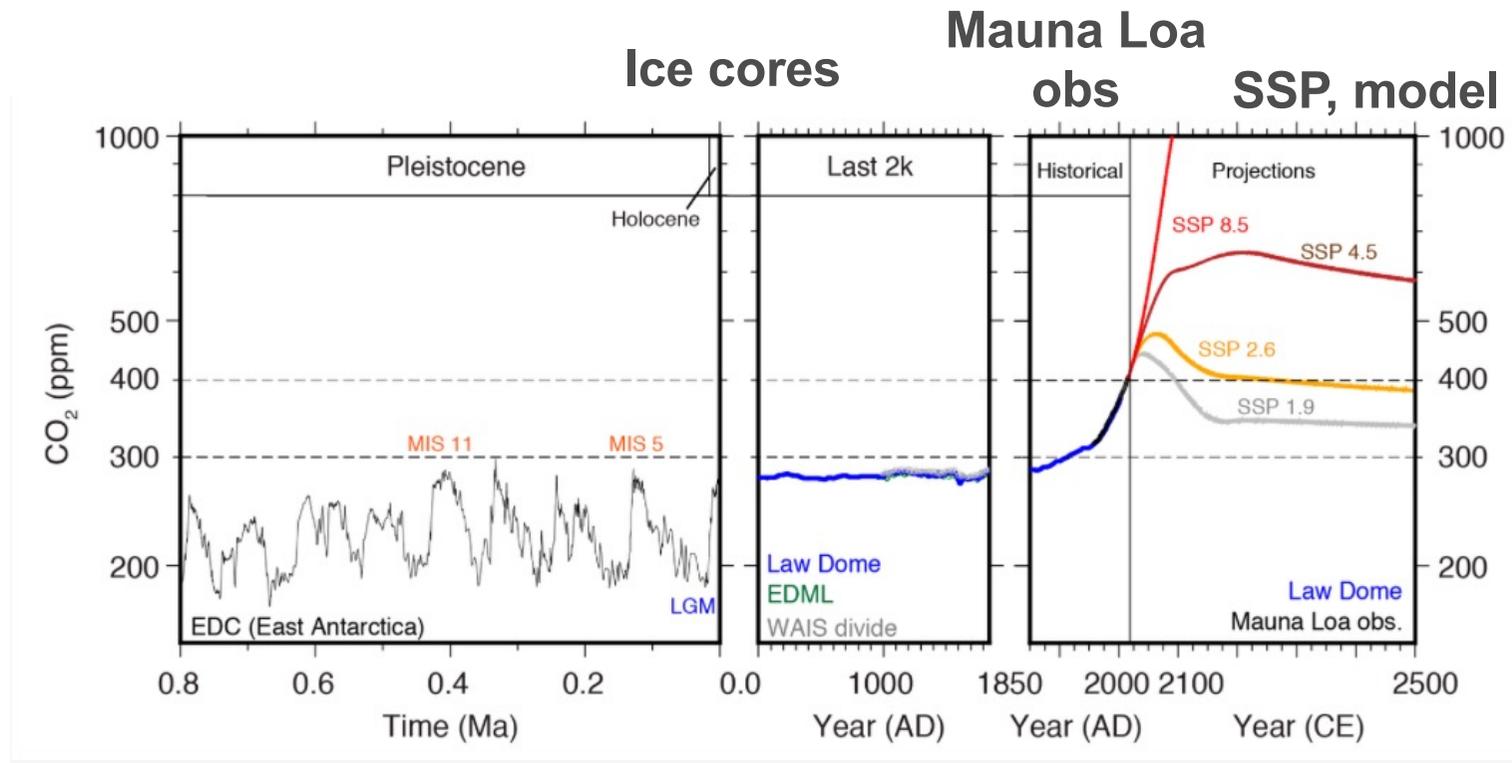
Policy assumptions and targets



Carbon Brief and IPCC

Paleo data, long-term observations and models

from the past to the future



Bracegirdle et al., Geoscience, 2019



THANKS!

Icons from <https://icons8.com>; <https://www.flaticon.com>. Parts of the graphics By PresentationGO.com.

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-
Mission 4 “Education and Research” - Component 2: “From research to business” - Investment
3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

