Lecture 1
6 January 2025

CM 615

Climate change Impacts & Adaptation

Introduction to the course

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Climate Studies, IIT Bombay

Course content

- **Introduction to Climate and Climate Change**: What is Climate, climate system and climate change? Overview of the climate system: what defines the climate system, how do energy balance works, what is global circulation system, energy transport

- **Anthropogenic Climate change:** Observing the changing state of climate system, variability & trend, Changes in atmospheric composition, Modern surface temperature records, the oceans and sea level rise, extreme weather, Sea-ice, Glaciers, Comparing with the climate over Earth's history, Climate data analysis

- **Climate models & their application:** Timescales of processes of the climate system, Validating climate models, Models used for making projections and scenarios, Projection of future climate change: surface temperature, precipitation, extreme weather, atmospheric and oceanic circulation, sea-level, cryosphere

- **Emission scenarios for future climate change:** Emission scenarios, factors that control emission scenarios

- **Impacts of Climate change:** Why should we care about climate change? Assessing climate impacts on key sectors and systems, Sea-level rise and coastal impacts, Ecosystem and biodiversity, Agriculture, Food-Water-Energy, Human health, Tipping points, Changes in biogeochemical cycles and its impact

- **Climate adaptation:** Adaptation principles. Economic Principles for Adaptation. Adaptation for water, agriculture, and health. Renewable energy for Adaptation, Adaptation for Community Resilience and Urban Resilience.

- **Climate engineering:** What is climate engineering? Solar radiation modifications, Carbon-dioxide removal methods, pros & cons of such methods, Emission reduction: the best viable way to look forward

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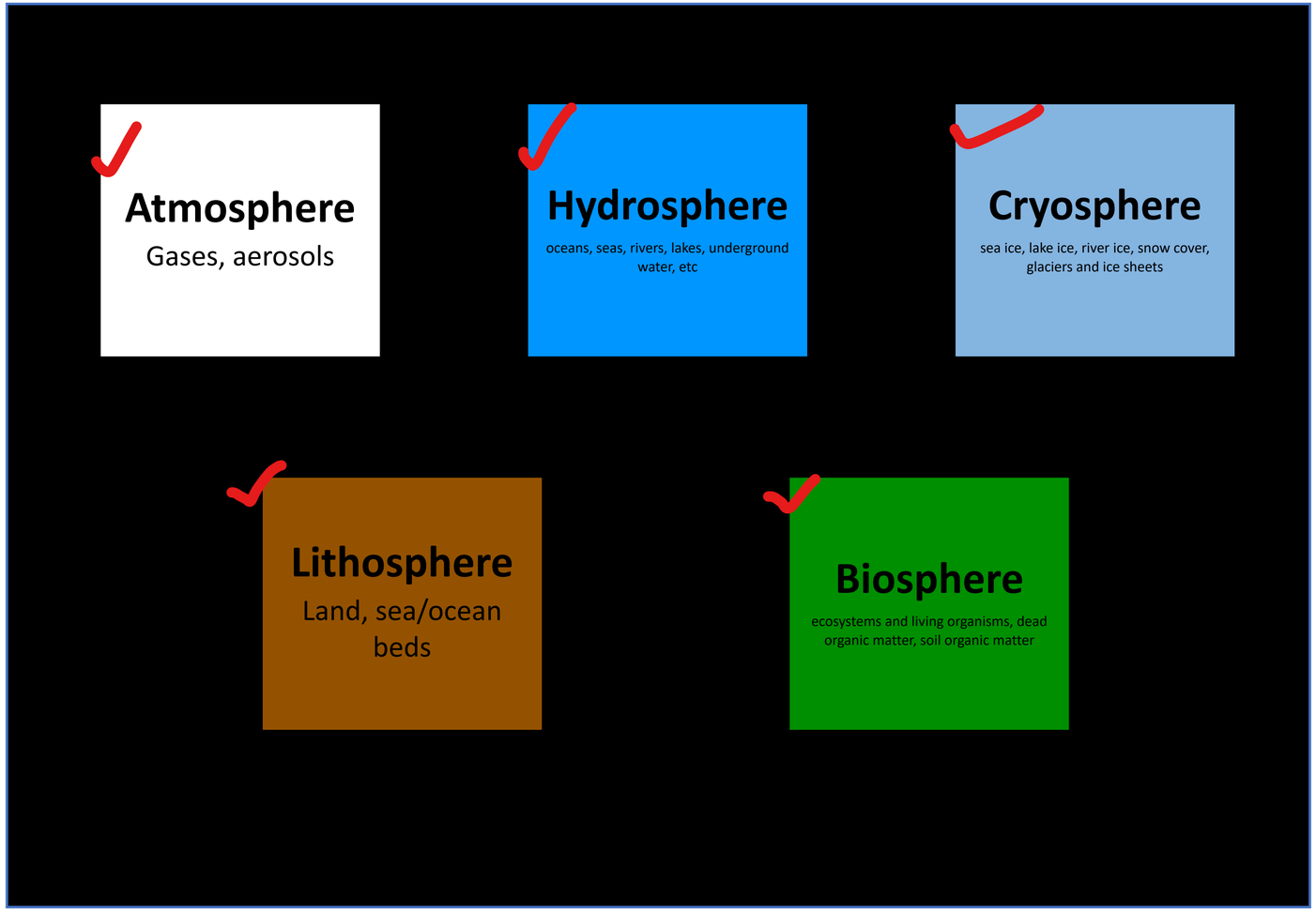
References:

- IPCC AR6 WGI & WGII
- Introduction to Modern Climate change, 3rd Edition, Andrew Dessler, Cambridge University Press
- Climate change and Climate modeling, David Neelin, Cambridge University Press, 2012
- Atmospheric Chemistry and Physics: From Air Pollution to Climate Change - 3rd ed, John H. Seinfeld and Spyros N. Pandis, 2016, Wiley-Blackwell.
- Additional notes & research articles to be provided as needed

General evaluation scheme

- Mid-semester exam —-> 25 %
- End-semester exam —-> 30 %
- Quizzes —-> 15 %
- Assignments —-> 30%
- Min. 80% attendance is mandatory

Climate system



In 1992, the United Nations' Framework Convention on Climate Change (UNFCCC) defined the climate system as 'the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions'.

Cubasch *et al.*, 2013

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Weather & Climate

- *"Weather describes the conditions of the atmosphere at a certain place and time with reference to temperature, pressure, humidity, wind, and other key parameters (meteorological elements)."*

Climate is what you expect. Weather is what actually happens

- *"The presence of clouds, precipitation, occurrence of special phenomena e.g. thunderstorms, dust storms, tornados and others" defines weather*

- Mawsynram, Meghalaya, Wettest place in India, 11,873 mm

- Climate is usually defined as the average of weather. Typically, the period for averaging is 30 years (WMO- World Meteorological Organization)

- Temperature
- Precipitation
- Wind

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Cubasch *et al.*, 2013

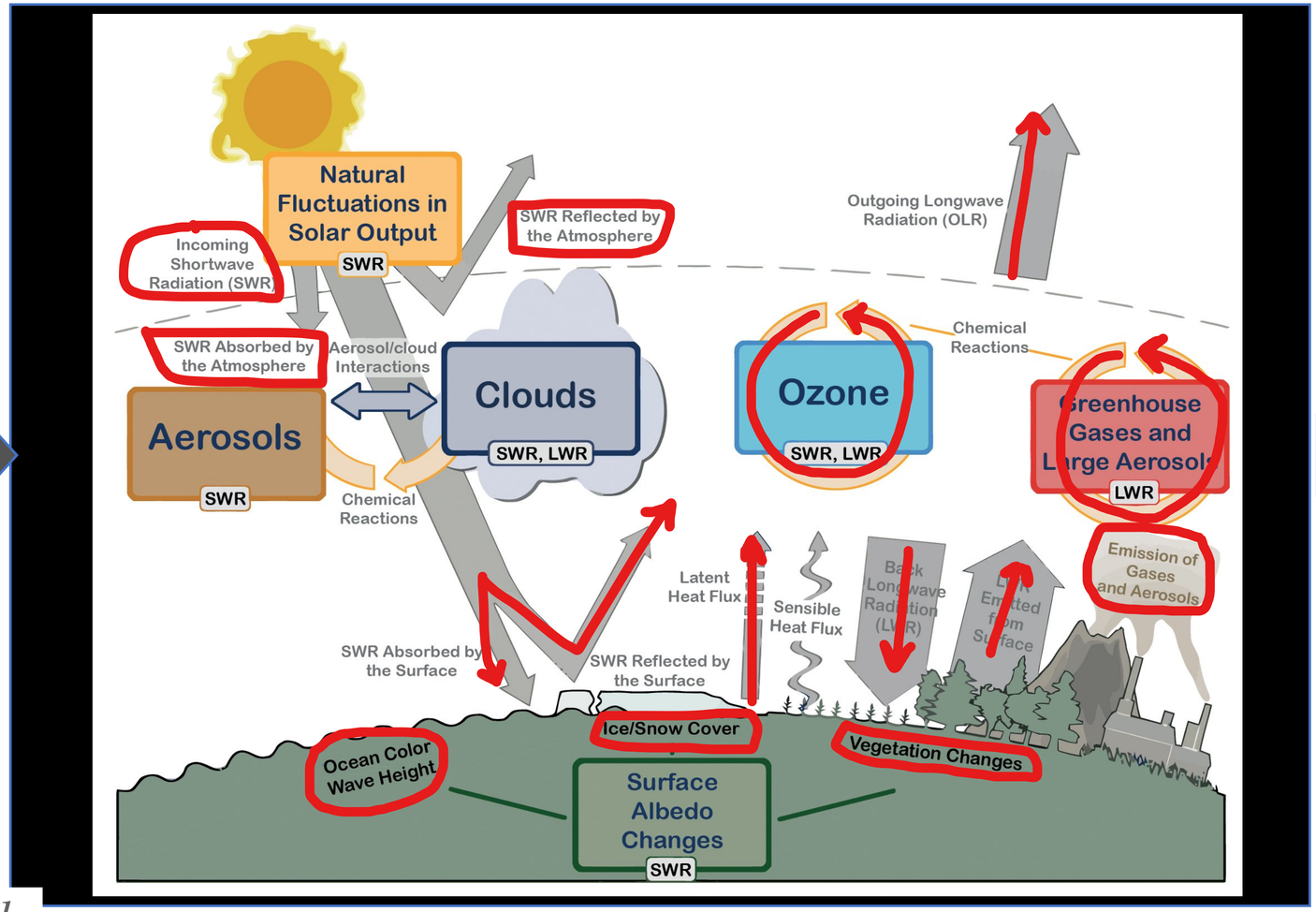
How does Climate change?

★ ***The key point is that when we perturb any of the components of the climate system we ultimately affect the planetary energy budget***

Perturb the system

NASA

Human activities



Response of the system

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GHGs, aerosols, Land-use-land-cover,

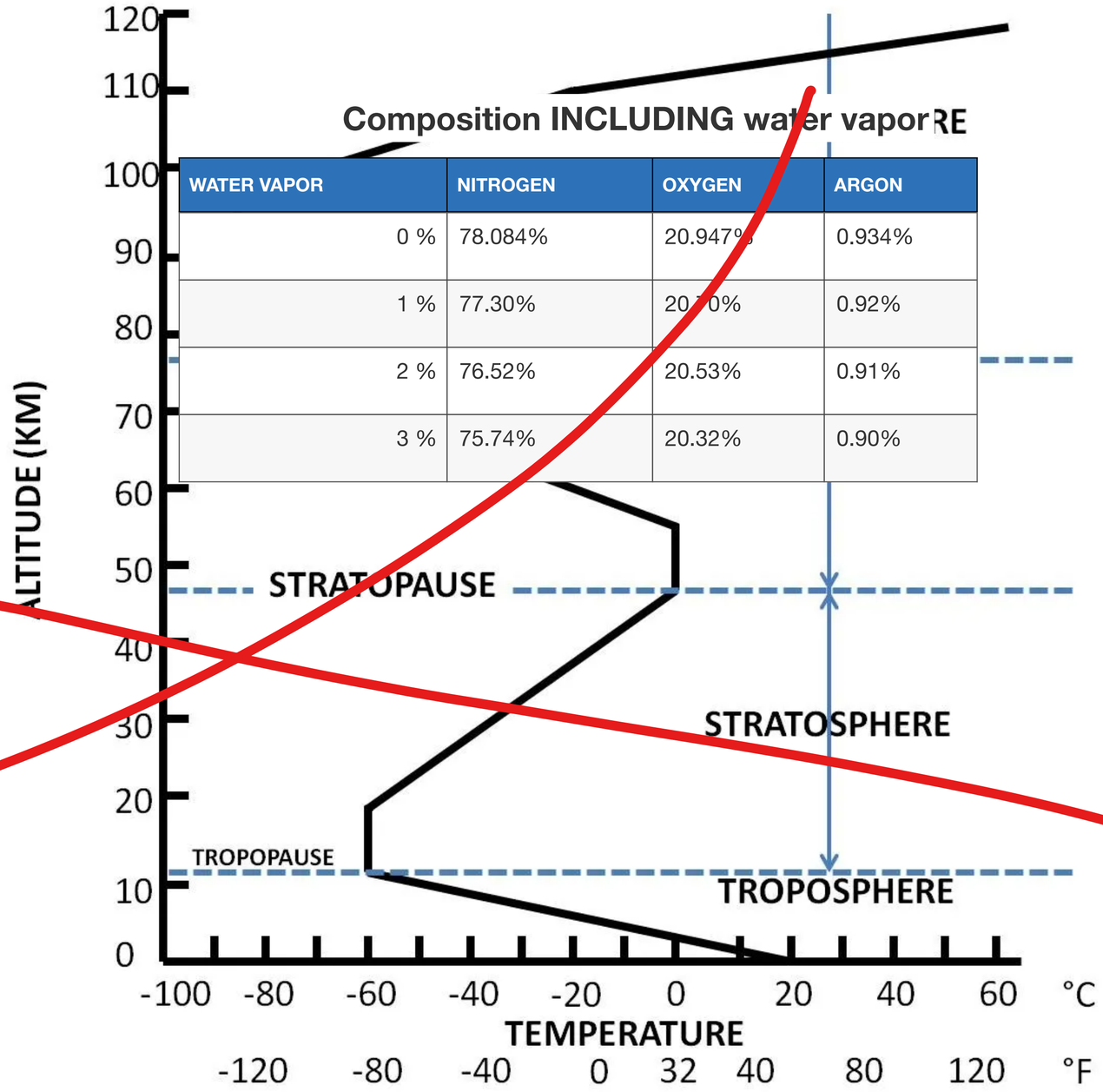
Cubasch *et al.*, 2013

Atmosphere

Composition EXCLUDING water vapor

GAS	SYMBOL	CONTENT
Nitrogen	N2	78.084%
Oxygen	O2	20.946%
Argon	Ar	0.934%
Carbon dioxide	CO2	420 parts per million
Neon	Ne	18.182 parts per million
Helium	He	5.24 parts per million
Methane	CH4	1.92 parts per million
Krypton	Kr	1.14 parts per million
Hydrogen	H2	0.55 parts per million
Nitrous oxide	N2O	0.33 parts per million
Carbon monoxide	CO	0.10 parts per million
Xenon	Xe	0.09 parts per million
Ozone	O3	0.07 parts per million
Nitrogen dioxide	NO2	0.02 parts per million
Iodine	I2	0.01 parts per million
Ammonia	NH3	trace

Source: NOAA



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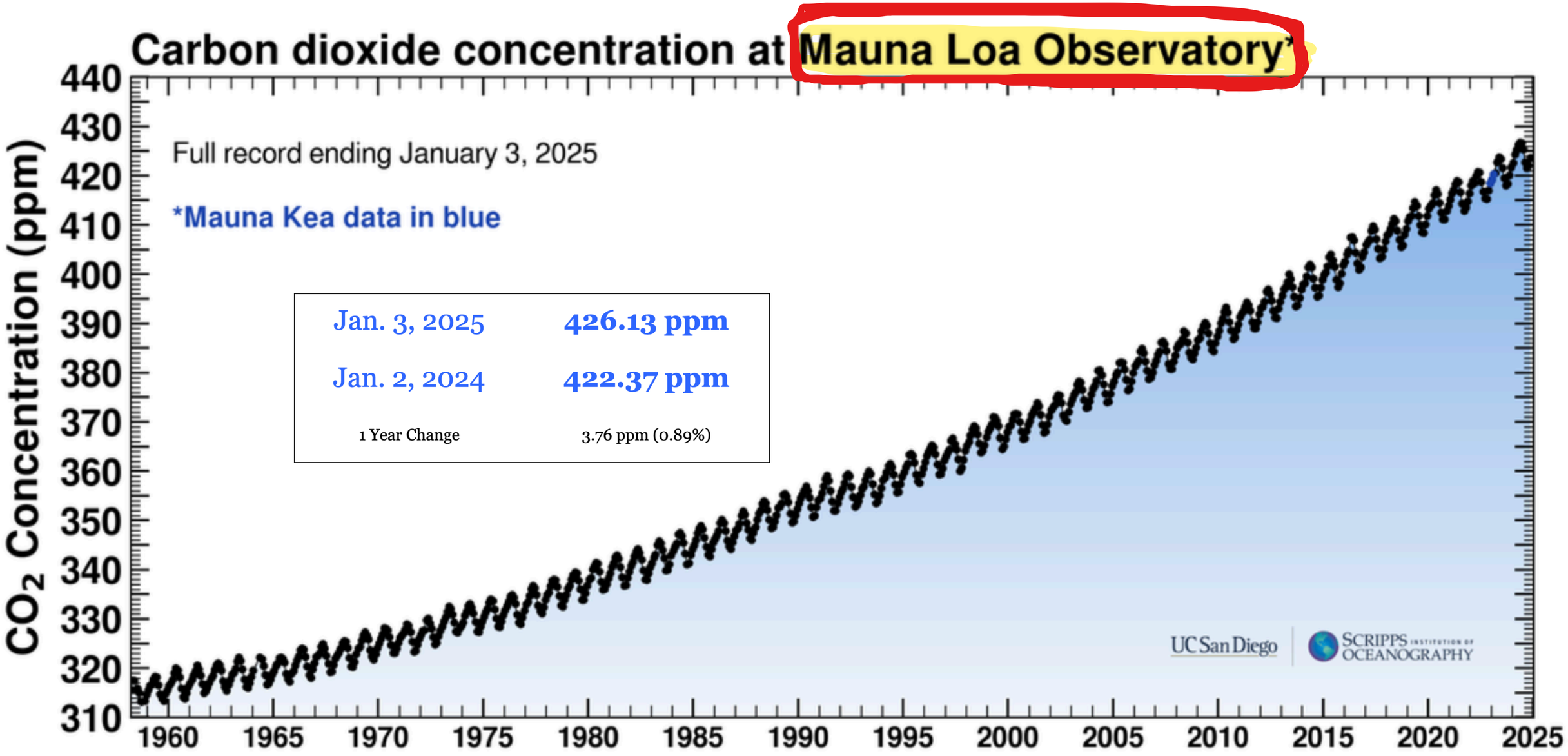
Composition INCLUDING water vapor

WATER VAPOR	NITROGEN	OXYGEN	ARGON
0 %	78.084%	20.947%	0.934%
1 %	77.30%	20.70%	0.92%
2 %	76.52%	20.53%	0.91%
3 %	75.74%	20.32%	0.90%

The Keeling curve



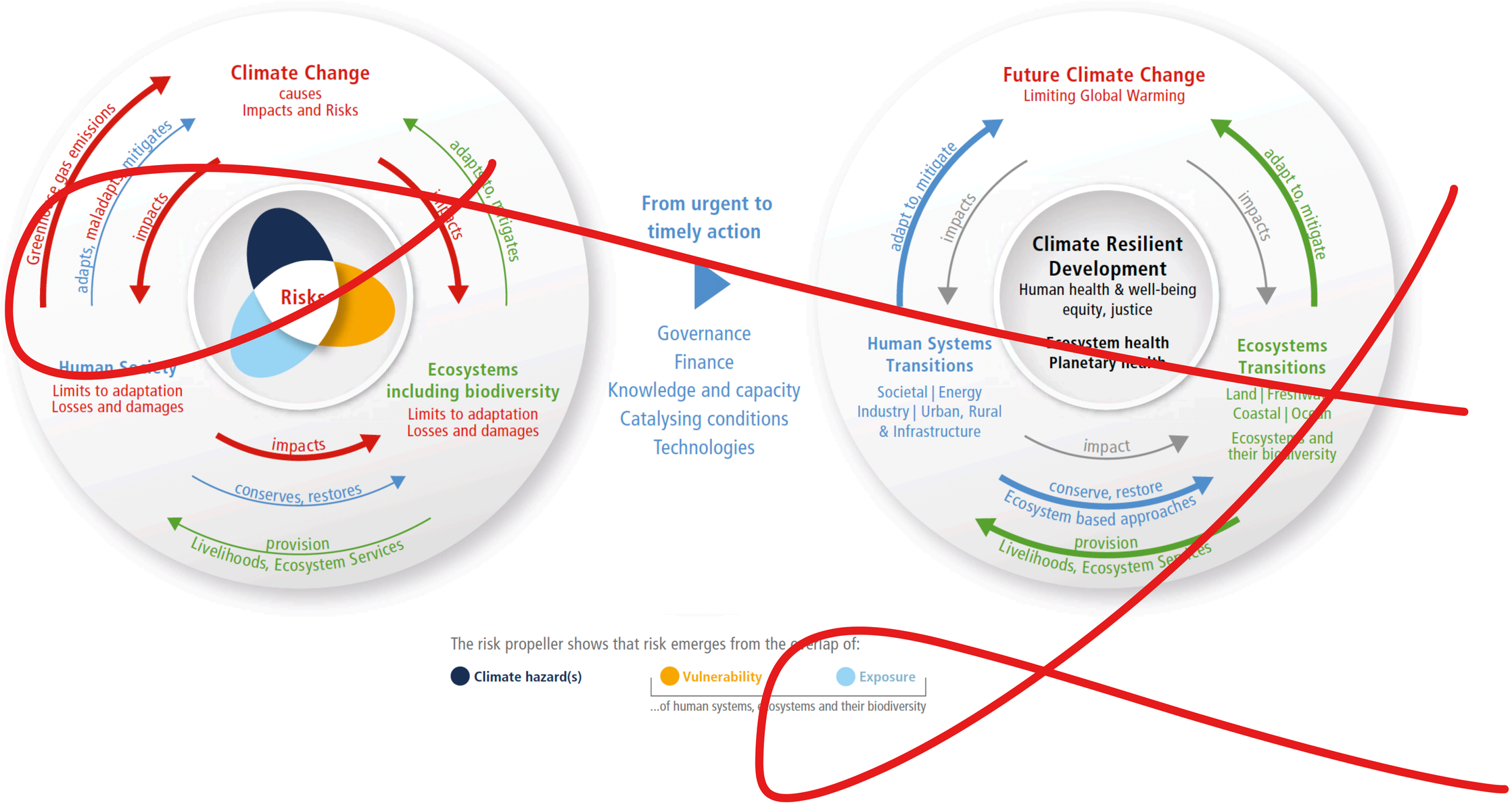
ADAPTATION

- Addresses the effects of the consequences;
- The IPCC defines adaptation as "process of adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploits beneficial opportunities";
- A typical case of adaptation for aviation would be improvements in coastal area airports' defences against sea level rise and reinforce infrastructure and equipment in remote and exposed locations in case of air navigation service providers.

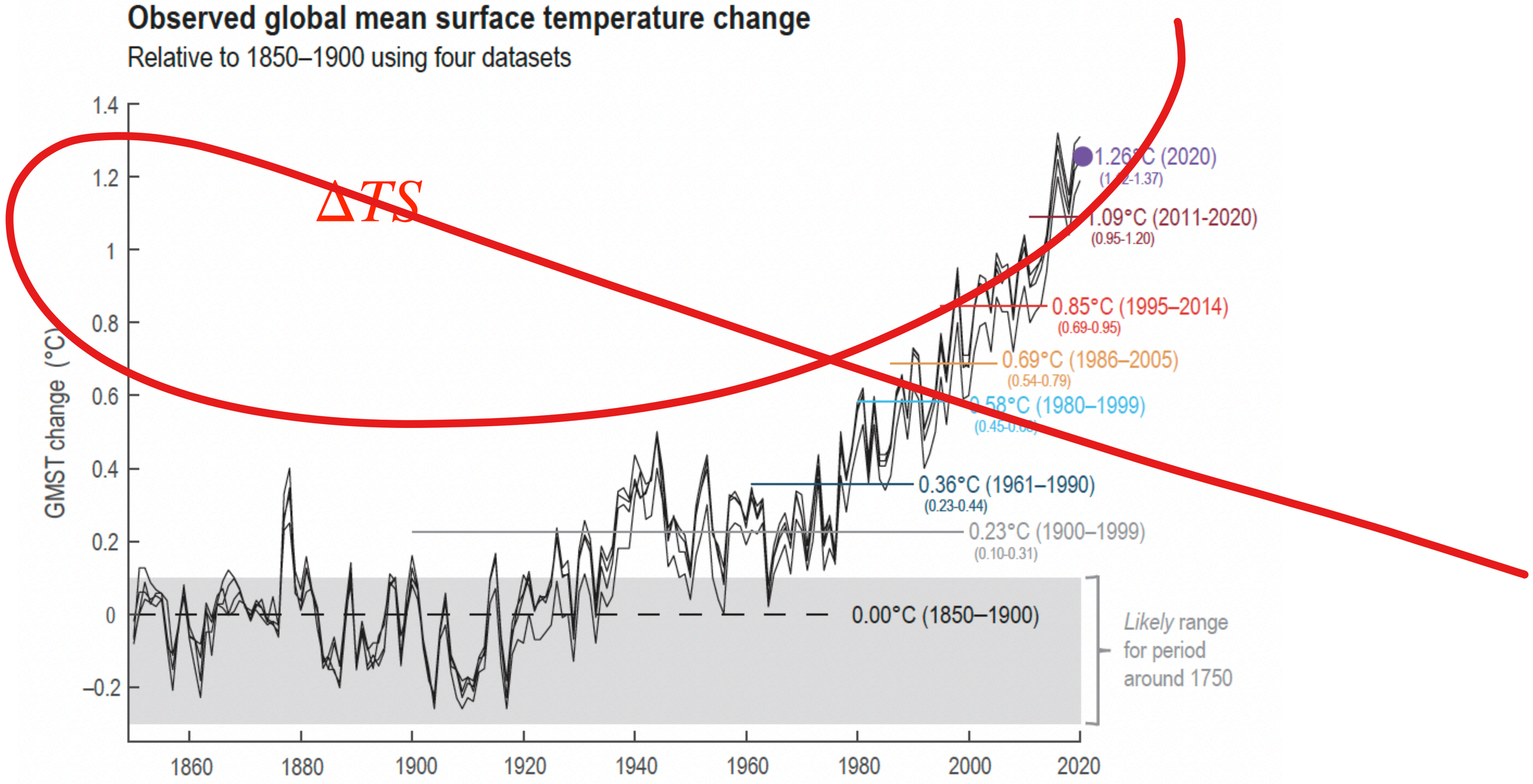
MITIGATION

- Addresses the causes of climate change and is the action taken to stabilize or reduce GHG concentrations;
- The IPCC defines mitigation as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases";
- An example of a typical mitigation measure for aviation would be optimizing the air traffic management systems to enable more direct routings and therefore reducing GHG emissions.

Inter-relationships



“Human society causes climate change. Climate change, through hazards, exposure and vulnerability generates impacts and risks that can surpass limits to adaptation and result in losses and damages. Human society can adapt to, maladapt and mitigate climate change, ecosystems can adapt and mitigate within limits. Ecosystems and their biodiversity provision livelihoods and ecosystem services. Human society impacts ecosystems and can restore and conserve them.”



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IPCC AR6, Chen et al. 2021

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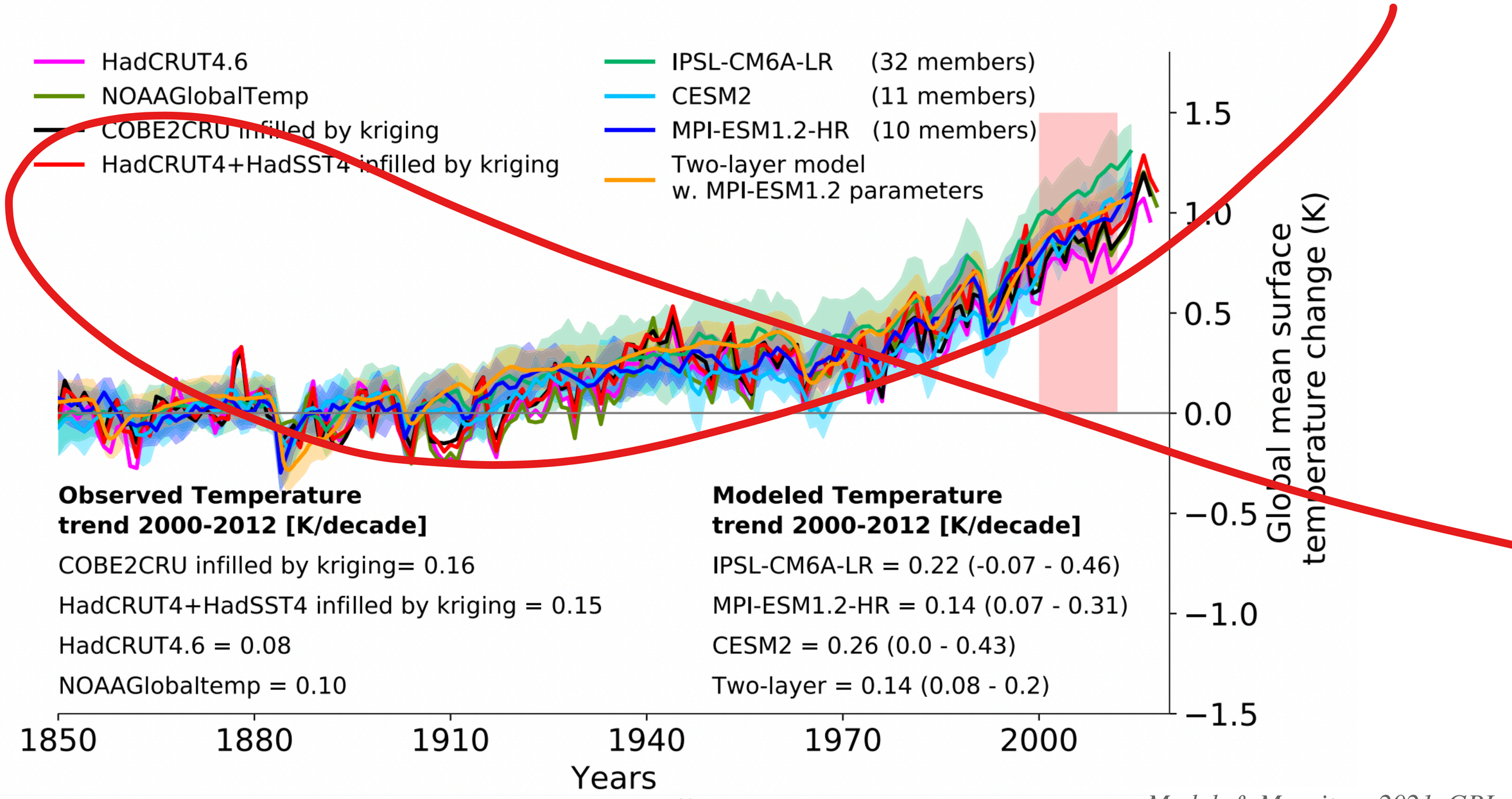
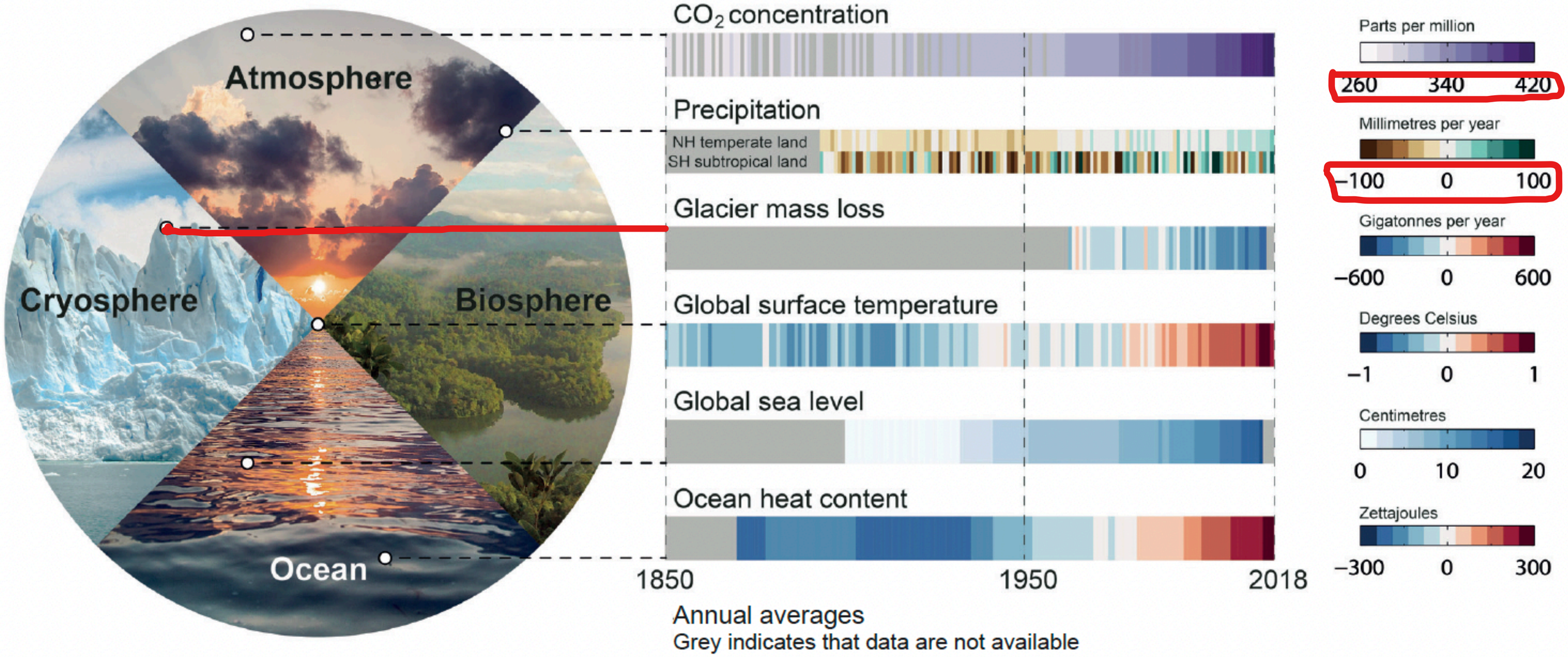


Modak & Mauritsen 2021, GRL

Climate change (since 1850…)



IPCC AR6, Chen et al. 2021

Datasets and baselines used are: (i) CO2: Antarctic ice cores (Lüthi et al., 2008; Bereiter et al., 2015) and direct air measurements (Tans and Keeling, 2020) (see Figure 1.5 for details); (ii) precipitation: Global Precipitation Climatology Centre (GPCC) V8 (updated from Becker et al., 2013), baseline 1961–1990 using land areas only with latitude bands 33N–66N and 15S–30S; (iii) glacier mass loss: Zemp et al. (2019); (iv) global surface air temperature (GMST): HadCRUT5 (Morice et al., 2021), baseline 1961–1990; (v) sea level change: (Dangendorf et al., 2019), baseline 1900–1929; (vi) ocean heat content (model–observation hybrid): Zanna et al. (2019), baseline 1961–1990.

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What happened in the past?

- Snowball earth — The Snowball Earth period occurred between 720 and 630 million years ago. The period was caused by low volcanic carbon dioxide emissions and weathering of volcanic rocks in what is now Canada.
- Glacial-Interglacial cycles
- Very hot planet
- Dinosaurs extinction 66 Ma — The end of the Cretaceous Period.
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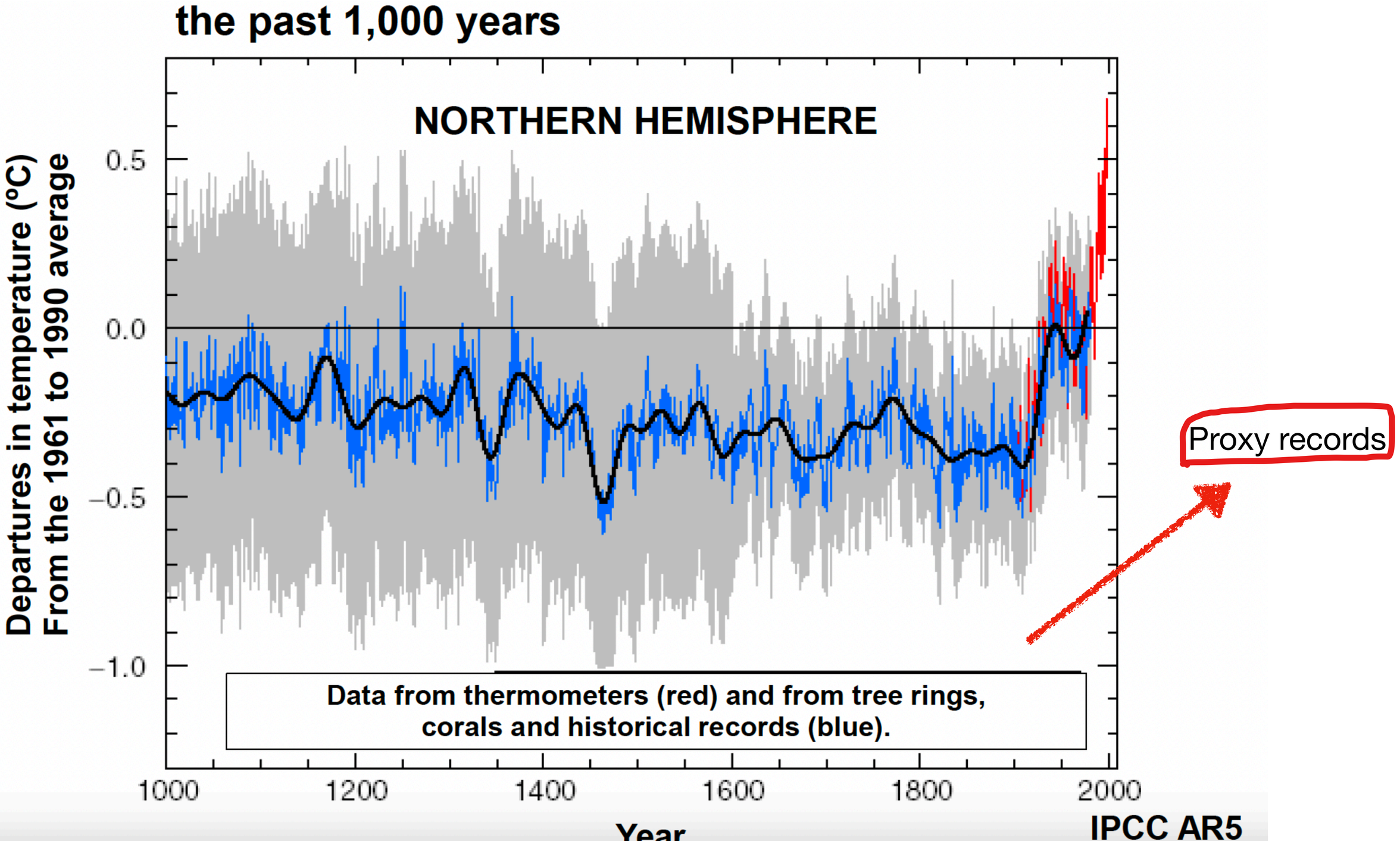
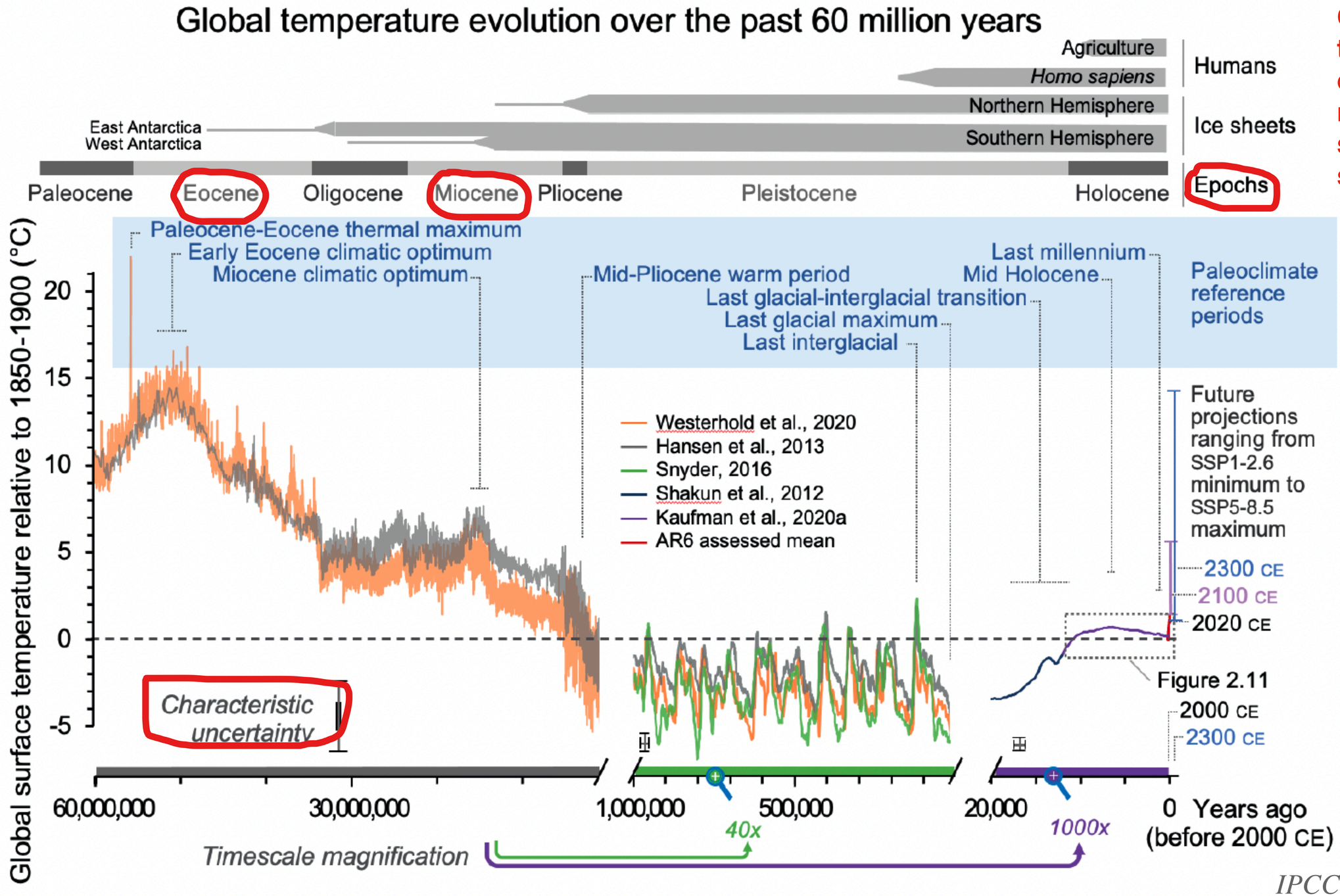
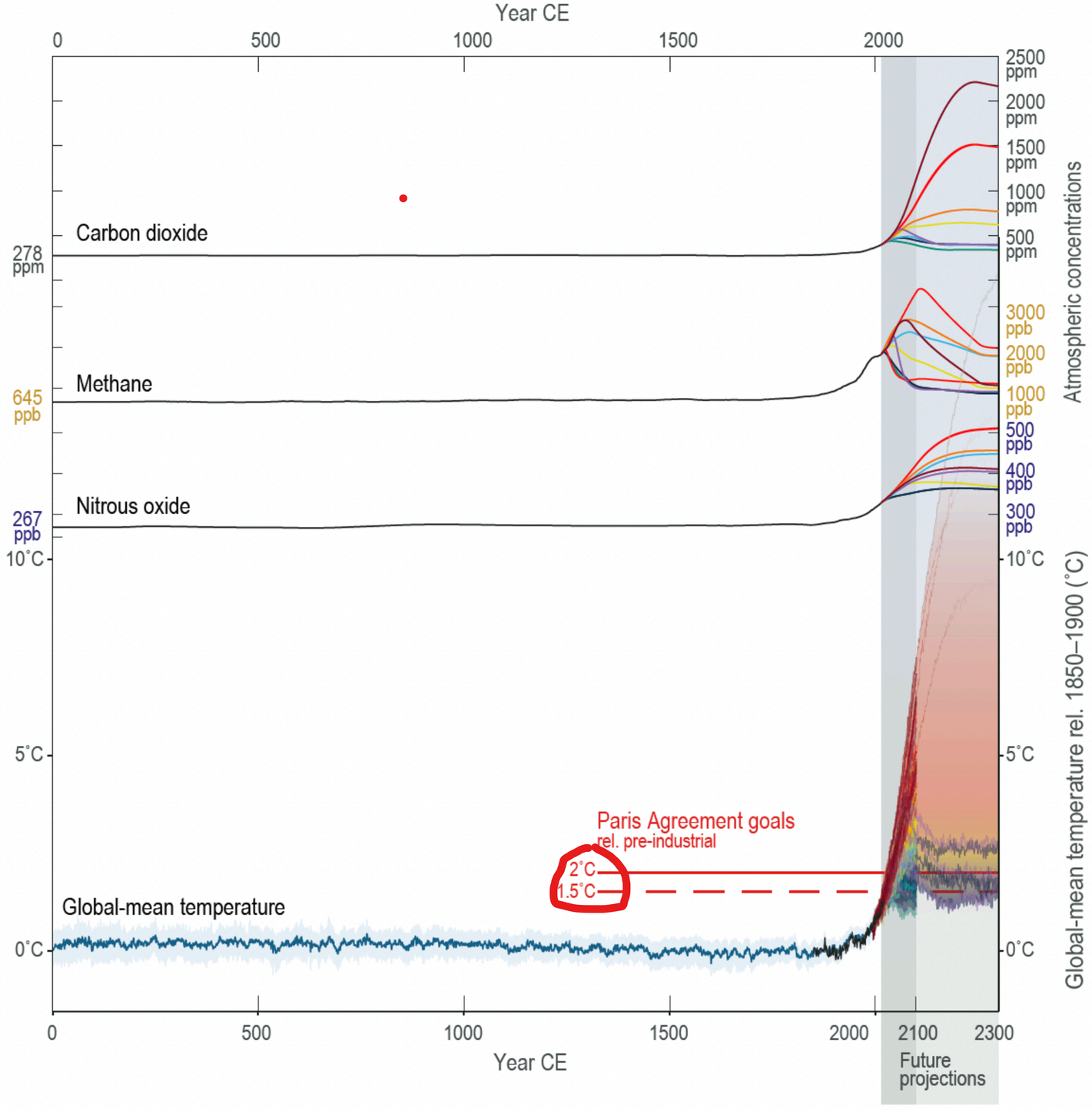

the past 1,000 years
NORTHERN HEMISPHERE
Departures in temperature (°C)
From the 1961 to 1990 average
0.5
0.0
−0.5
−1.0
1000
1200
1400
1600
1800
2000
Year
Data from thermometers (red) and from tree rings,
corals and historical records (blue).
Proxy records
IPCC AR5



Global mean surface temperature GMST over the past 60 Myr relative to 1850–1900 shown on three time scales

IPCC AR6, Chen et al. 2021



IPCC AR6, Chen et al. 2021

Historical and projected future concentrations of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) and global mean temperatures (GMST)

GMST temperature reconstructions over the last 2000 years were compiled by the PAGES 2k Consortium (2017, 2019) (grey line, with 95% uncertainty range) referenced against the 1850–1900 period.

Future GSAT temperature projections are from CMIP6 ESM models across all concentration-driven SSP scenario projections. The discontinuity around year 2100 for CMIP6 temperature projections results from the fact that not all ESM models ran each scenario past 2100. The grey vertical band indicates the future 2015–2300 period.

The concentrations used to drive CMIP6 Earth system models are derived from ice core, firn and instrumental datasets (Meinshausen et al., 2017) and projected using an emulator.The colours of the lines indicate the SSP scenarios used in this Report