Copertina

Corso di Fisica dell'Atmosfera

# Cenni di climatologia e cambiamenti climatici

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# Sommario della lezione

- Definizione di clima secondo WMO (strettamente meteorologico)
- Definizione di sistema clima (visione integrata)
- Paleoclima e le sue fonti
- Cambiamenti climatici in atto
- Scenari futuri di clima
- Bibliografia

# Cos'è il clima: definizione World Meteorological Organization

Climate, sometimes understood as the "average weather," is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years.

The classical period is **30 years**, as defined by the World Meteorological Organization (WMO).

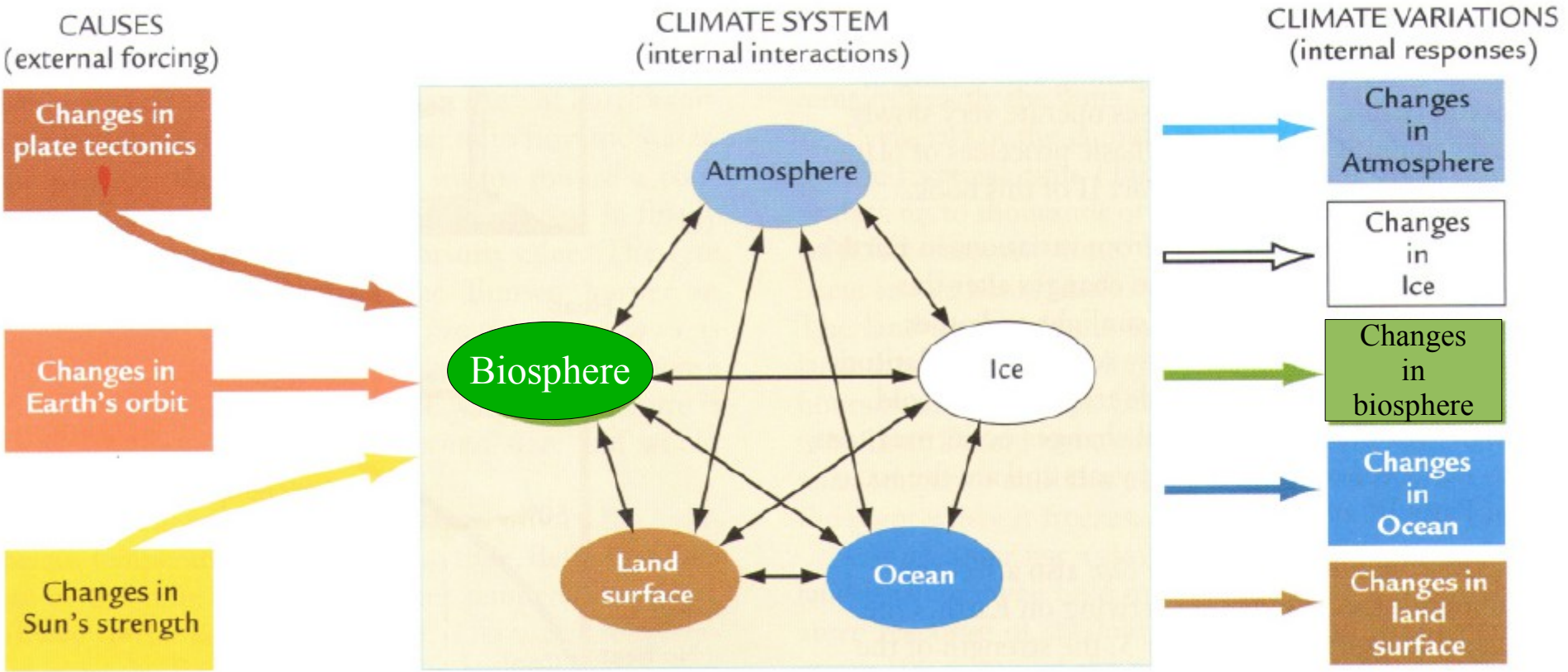
Questa definizione focalizza l'attenzione solo sull'atmosfera

Climate in a wider sense is the state, including a statistical description, of the climate system.

Fonte: http://www.wmo.int/pages/prog/wcp/ccl/faqs.php

# Il sistema clima

Una visione più ampia che tiene conto delle interazioni tra tutti i sistemi interagenti con l'atmosfera



# Cosa sappiamo del clima passato

- Ci sono evidenze che a Terra esiste da datano l'esistenza della terra a 4.5 Gy
- Non ci sono informazioni disponibili antecedenti i 300 My da oggi
- Ci sono evidenze di notevoli cambiamenti del clima passato negli ultimi 300 My

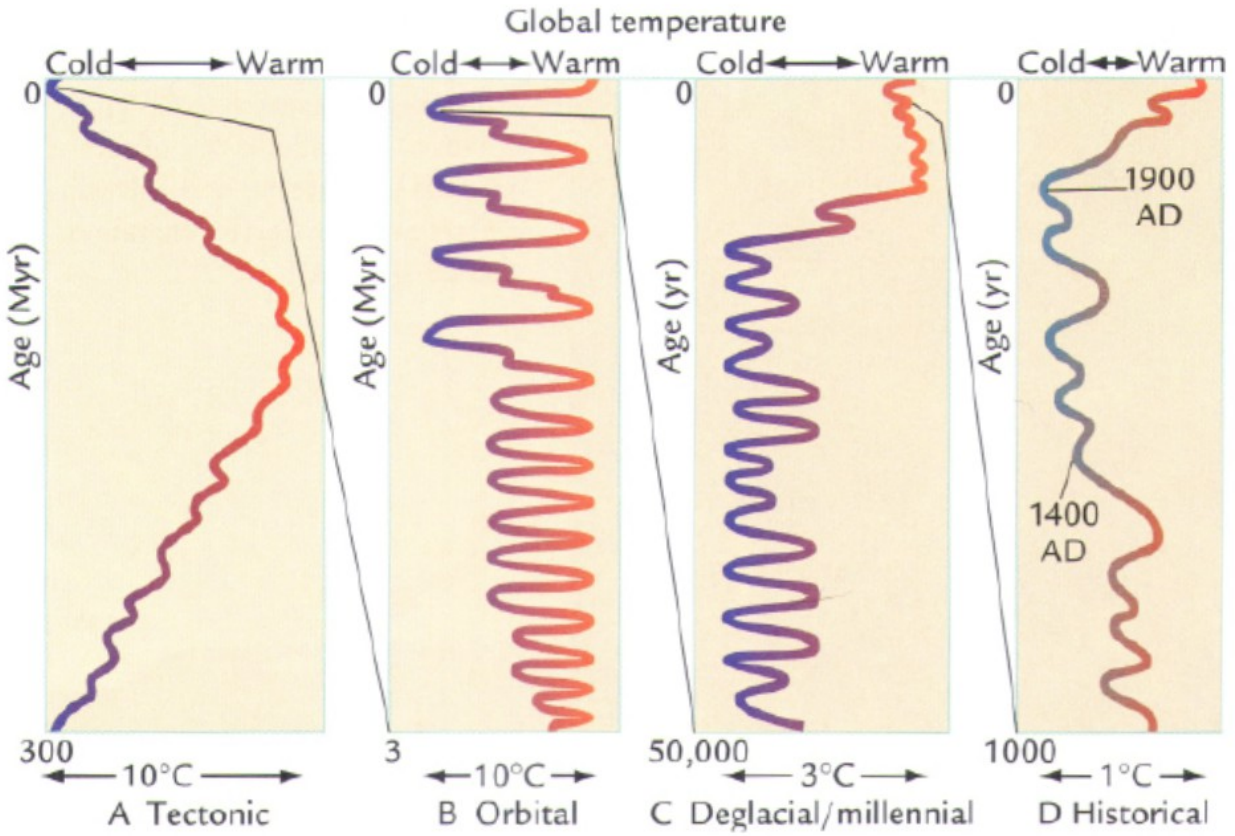



**FIGURE 1-3 Time scales of climate change** Changes in Earth's climate span several time scales, arrayed from longer to shorter: (A) the last 300 million years, (B) the last 3 million years, (C) the last 50,000 years, and (D) the last 1000 years. Here progressively smaller changes in climate at successively shorter time scales are magnified out from the larger changes at longer time scales.

# Tempi di risposta delle diverse componenti del sistema clima alle forzanti esterne

**TABLE 1.1 Response Times of Various Climate System Components**

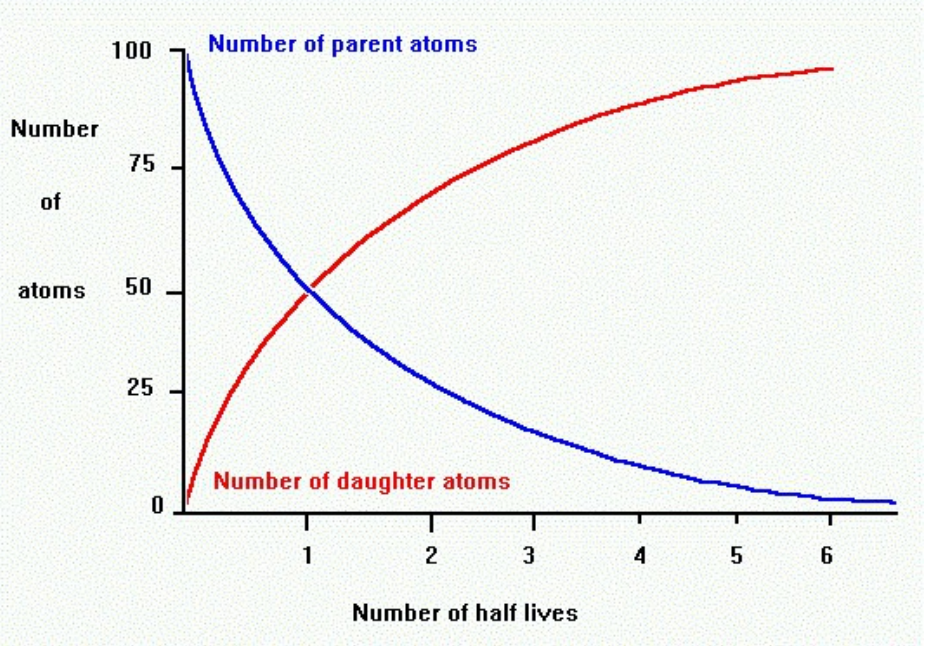
| Component | Response time (range) | Example |
|---|---|---|
| | **Fast responses** | |
| Atmosphere | Hours to weeks | Daily heating and cooling<br>Gradual buildup of heat wave |
| Land surface | Hours to months | Daily heating of upper ground surface<br>Midwinter freezing and thawing |
| Ocean surface | Days to months | Afternoon heating of upper few feet<br>Warmest beach temperatures late in summer |
| Vegetation | Hours to decades/centuries | Sudden leaf kill by frost<br>Slow growth of trees to maturity |
| Sea ice | Weeks to years | Late-winter maximum extent<br>Historical changes near Iceland |
| | **Slow responses** | |
| Mountain glaciers | 10–100 years | Widespread glacier retreat in 20th century |
| Deep ocean | 100–1500 years | Time to replace world's deep water |
| Ice sheets | 100–10,000 years | Advances/retreats of ice sheet margins<br>Growth/decay of entire ice sheet |

# Lo studio del clima passato: le fonti

- Fonti storiche e misure moderne
- Coralli
- Pollini
- Carote di ghiacci
- Anelli dei tronchi di alberi
- Sedimenti marini
- Sedimenti nei laghi
- Radio datazione

# Radio datazione

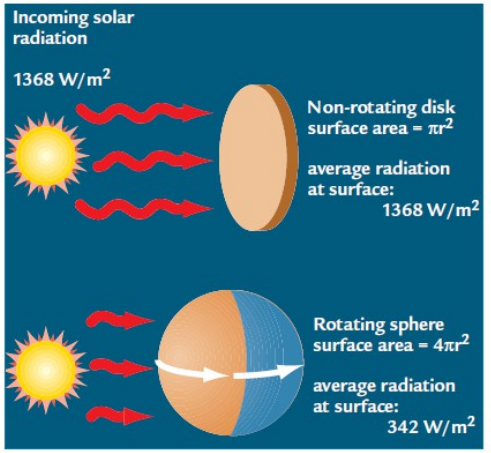
Un metodo usato parecchio negli ultimi decenni per datare campioni è quello della radio datazione che si basa sul decadimento radioattivo di alcuni isotopi naturali

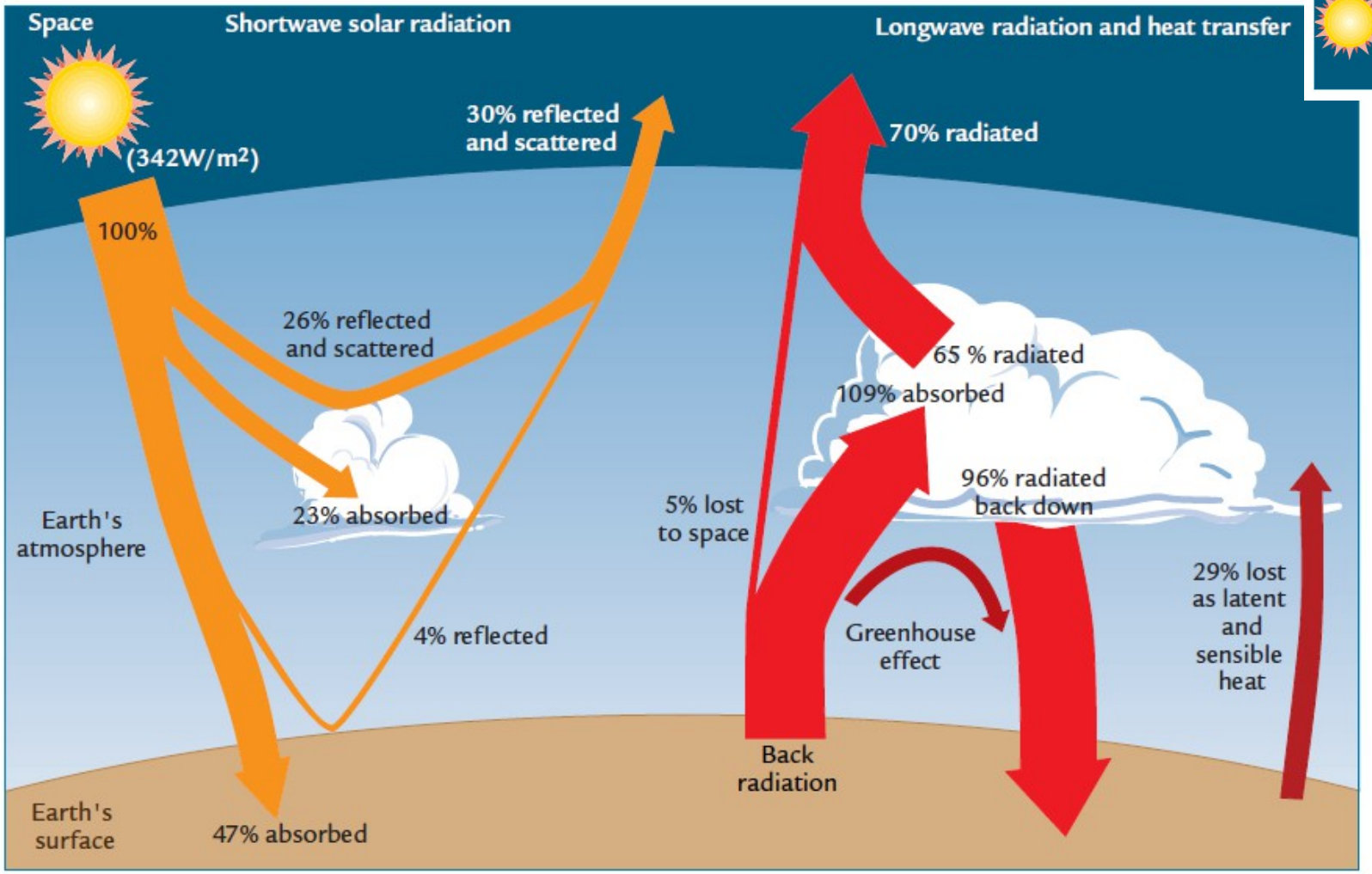



| Radioactive Parent | Stable Daughter | Half life |
|---|---|---|
| Potassium 40 | Argon 40 | 1.25 billion yrs |
| Rubidium 87 | Strontium 87 | 48.8 billion yrs |
| Thorium 232 | Lead 208 | 14 billion years |
| Uranium 235 | Lead 207 | 704 million years |
| Uranium 238 | Lead 206 | 4.47 billion years |
| Carbon 14 | Nitrogen 14 | 5730 years |

Ovviamente le incertezze non riguardano solo la misura radioattiva, ma anche il modo in cui il campione ha conservato la massa dei radio nuclei.

# Bilancio energetico planetario: l'importanza dell'effetto serra



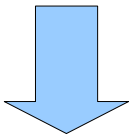
# I forzanti climatici

## 1-5 Climate Forcing

Three fundamental kinds of climate forcing exist in the natural world:

- *Tectonic processes* generated by Earth's internal heat affect its surface by means of processes that alter the basic geography of Earth's surface. These processes are part of the theory of plate tectonics, the unifying theory of the science of geology. Examples include the slow movement of continents, the uplift of mountain ranges, and the opening and closing of ocean basins. These processes operate very slowly over millions of years. The basic processes of plate tectonics are explained in Part II of this book.
- *Earth-orbital changes* result from variations in Earth's orbit around the Sun. These changes alter the amount of solar **radiation** (sunlight and other energy) received on Earth by season and by latitude (from the warm, low-latitude tropics to the cold, high-latitude poles). Orbital changes occur over tens to hundreds of thousands of years and are the focus of Parts III and IV.
- *Changes in the strength of the Sun* also affect the amount of solar radiation arriving on Earth. One example appears in Chapter 3: the strength of the Sun has slowly increased throughout the 4.55 Byr of Earth's existence. In addition, shorter-term variations that occur over decades or longer are part of the focus of Part V.

A fourth factor capable of influencing climate, but not in a strict sense part of the natural climate system, is the *effect of humans on climate*, referred to as **anthropogenic forcing.** This forcing is an unintended by-product of agricultural, industrial, and other human activities, and



Ipotesi antropogenica del riscaldamento globale



Fonte: Earth's Climate – Past and Future (Second Edition), by William Ruddiman, 2008,

# Evidenze di un riscaldamento globale anomalo: l'attuale ipotesi antropogenica $CH_4$

RG4001 Ruddiman: EARLY ANTHROPOGENIC HYPOTHESIS RG4001

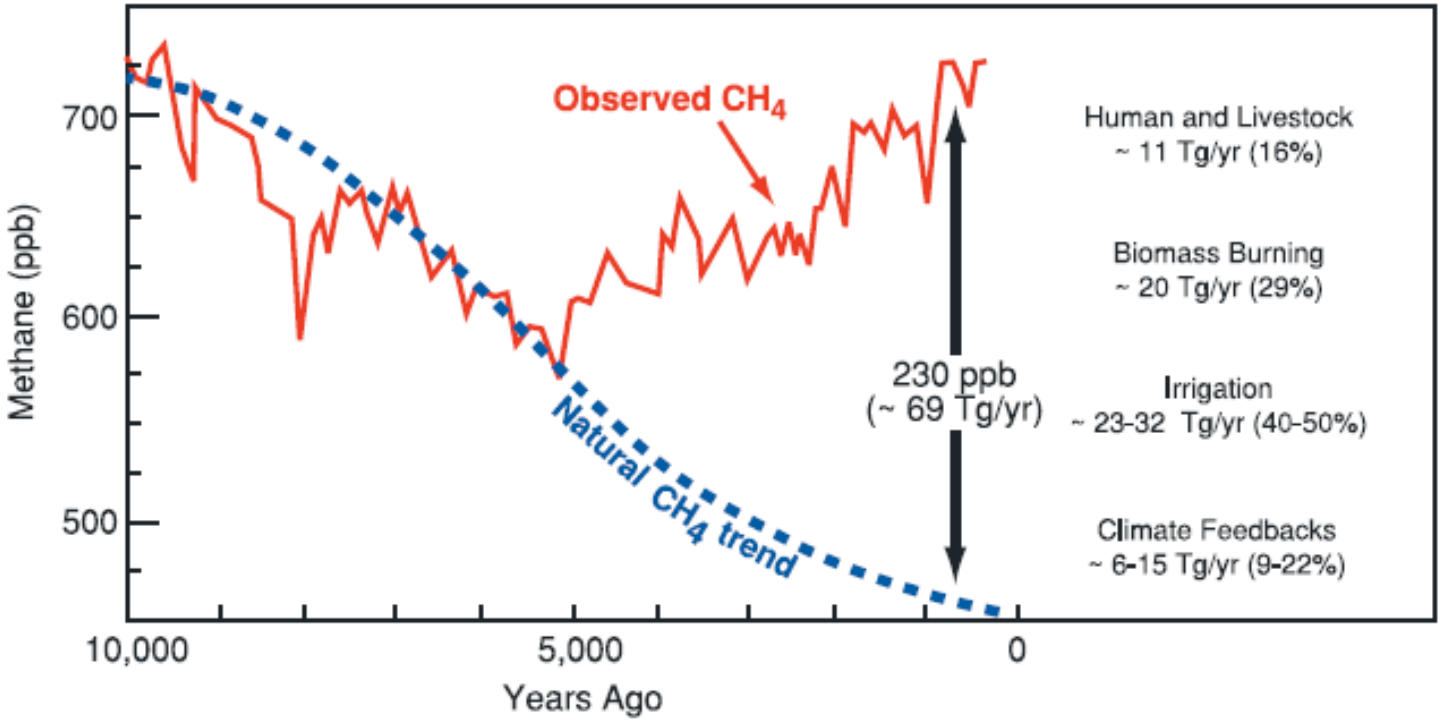



**Figure 12.** Estimated anthropogenic $CH_4$ anomaly of 230 ppb in the year 1500 accounted for by contributions from several sources: emissions from livestock and human waste (both linearly tied to human population), disproportionately large emissions from biomass burning and irrigation, and climate system feedbacks.

# Evidenze di un riscaldamento globale anomalo: l'attuale ipotesi antropogenica $CO_2$

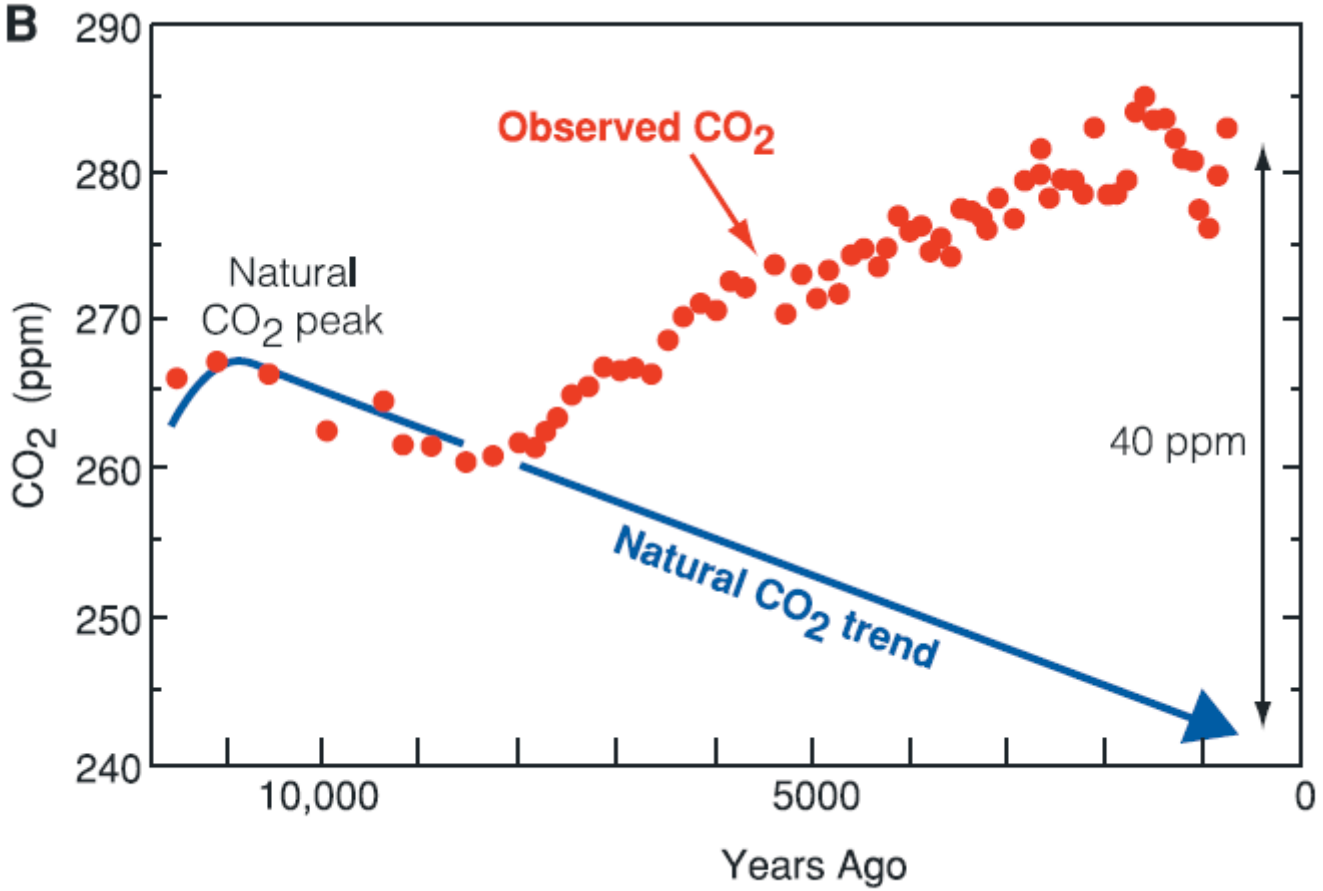



**Figure 1.** Early anthropogenic hypothesis. Human activities during the late Holocene causing increases in (a) $CH_4$ and (b) $CO_2$ in contrast to the downward trends during previous interglaciations. (c) Late Holocene greenhouse gas increases preventing much of the natural cooling that occurred in previous interglaciations.

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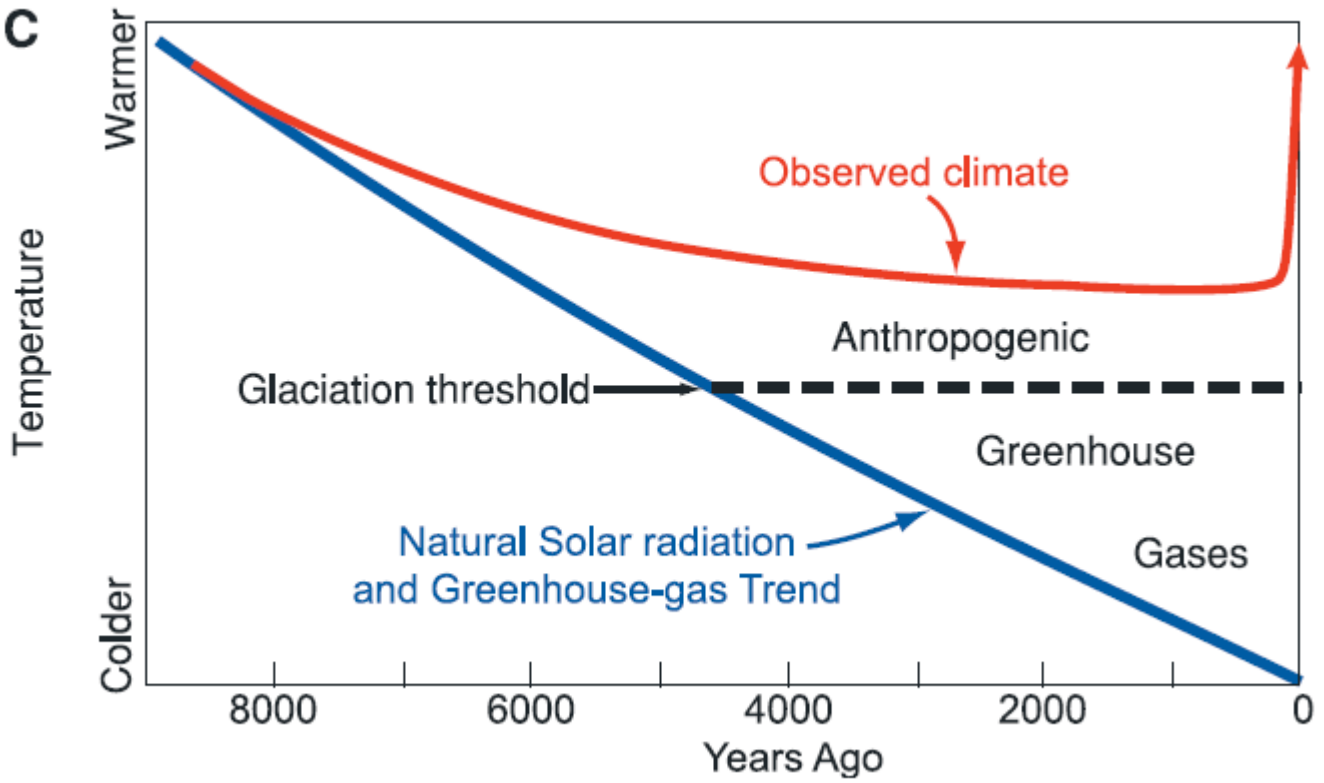


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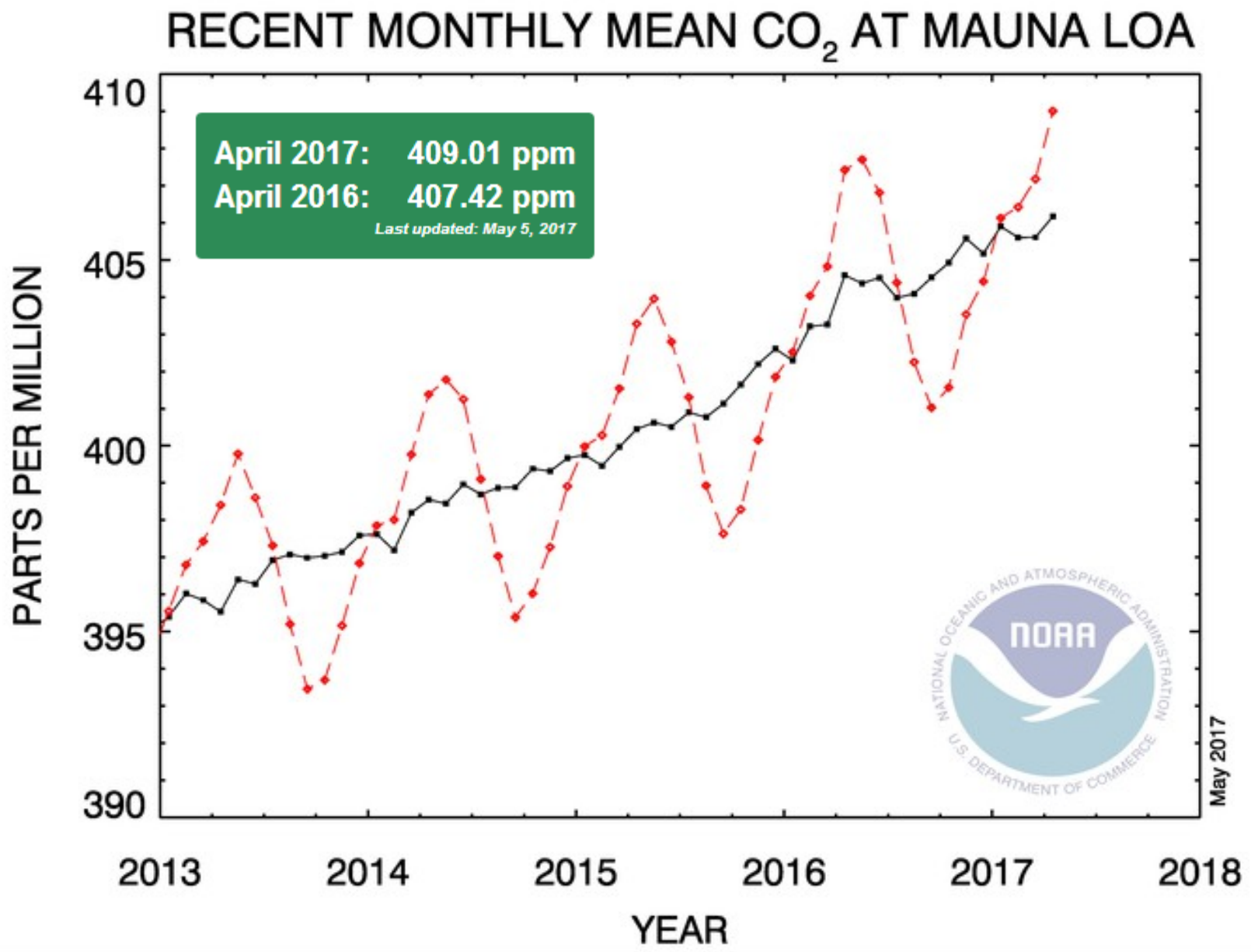
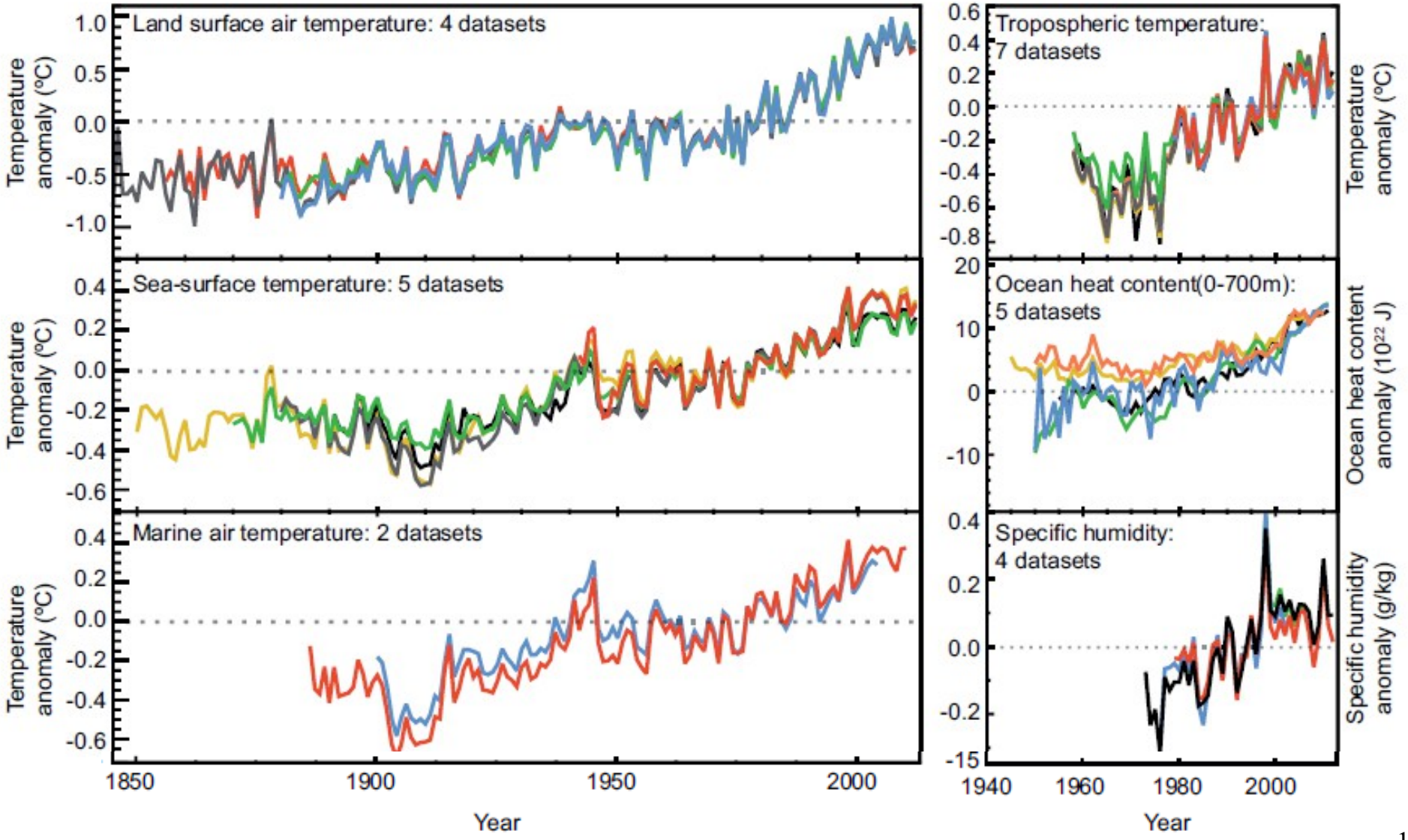
# Livelli attuali di CO2



# Evidenze dei cambiamenti nell'ultimo secolo



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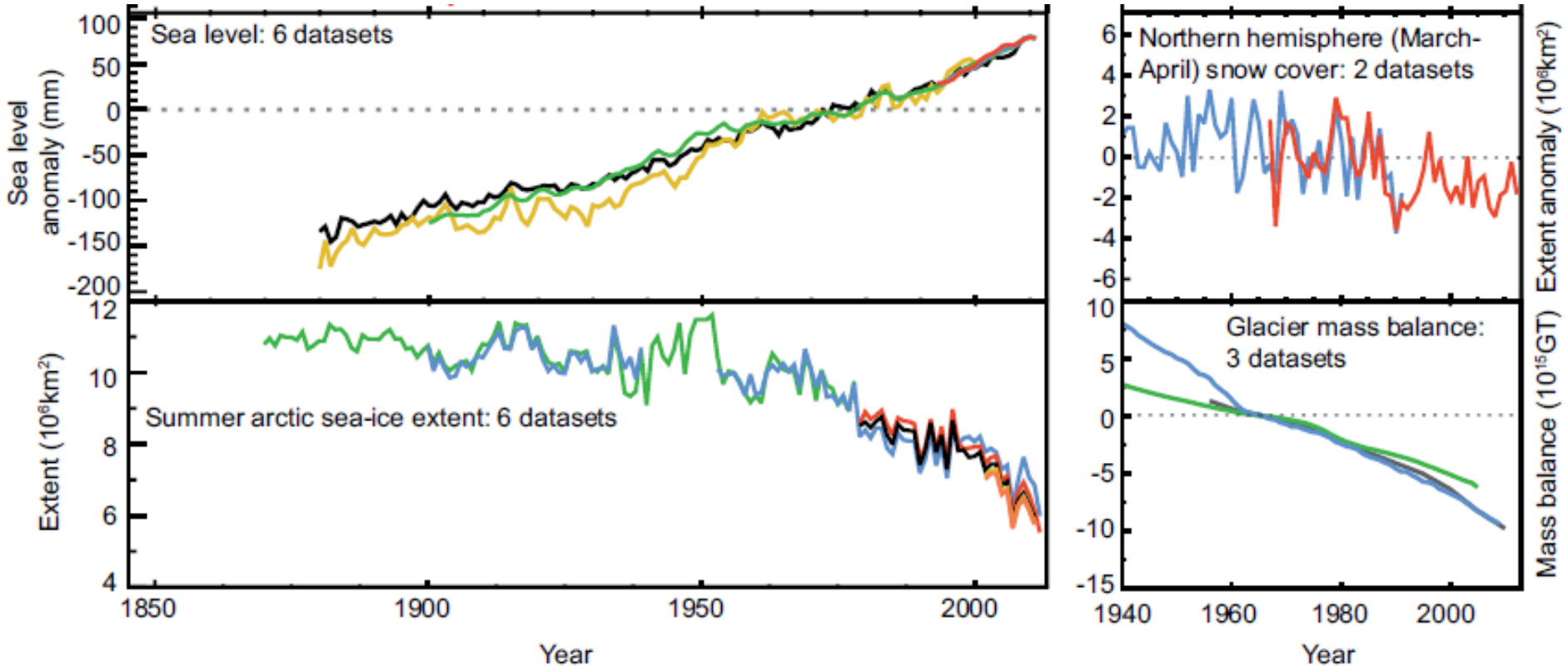
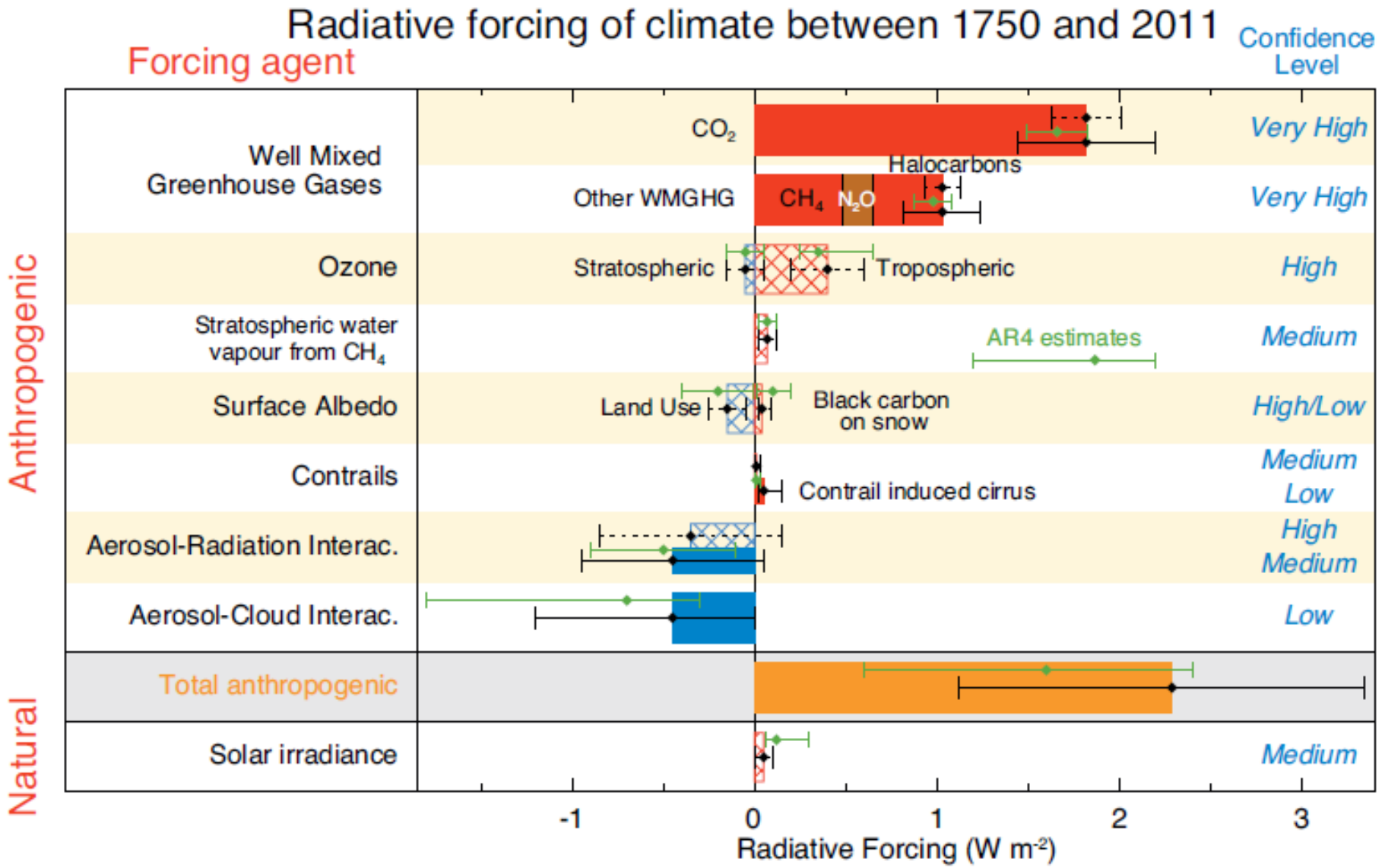
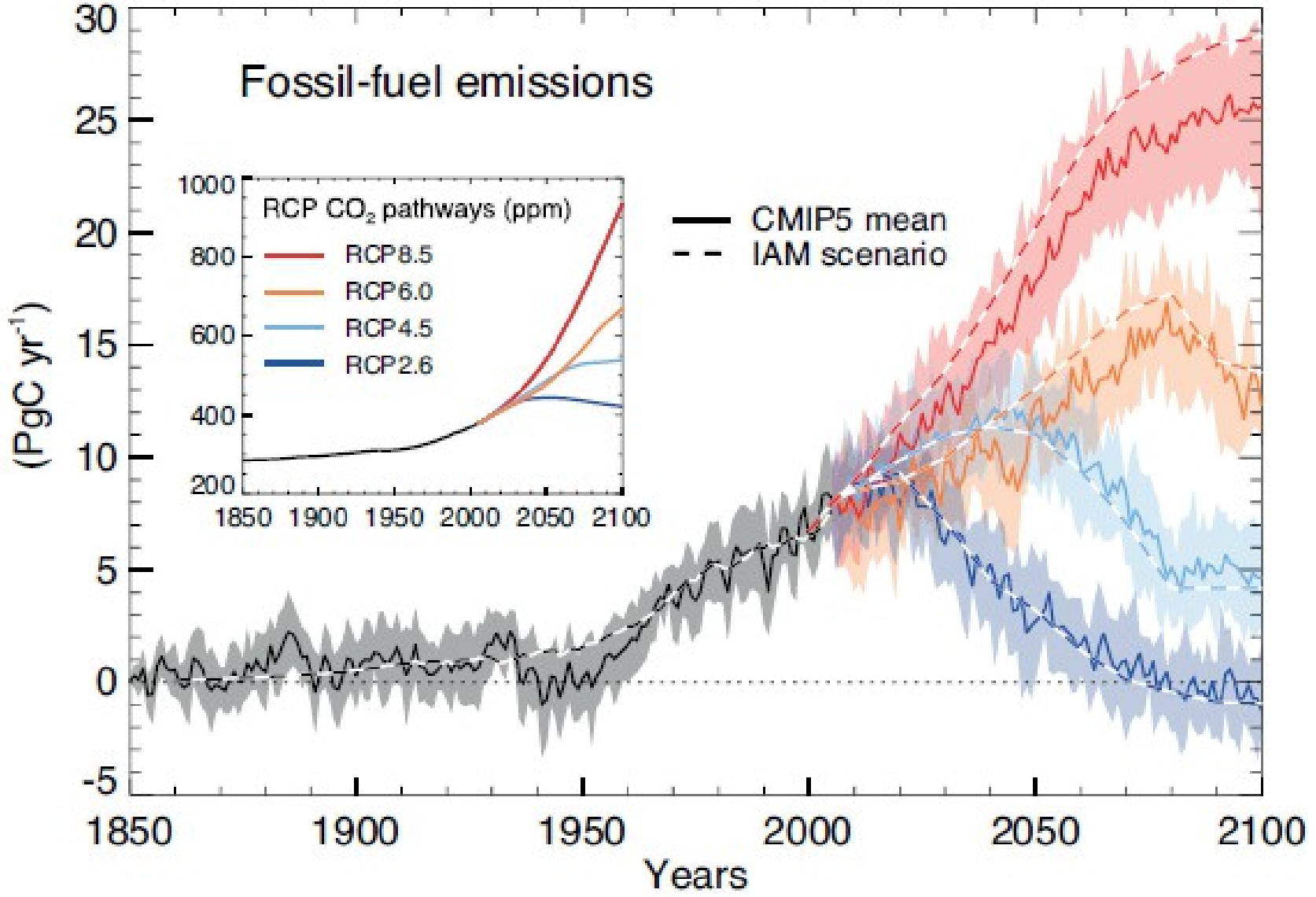


# Elementi che agiscono da forzante sul clima



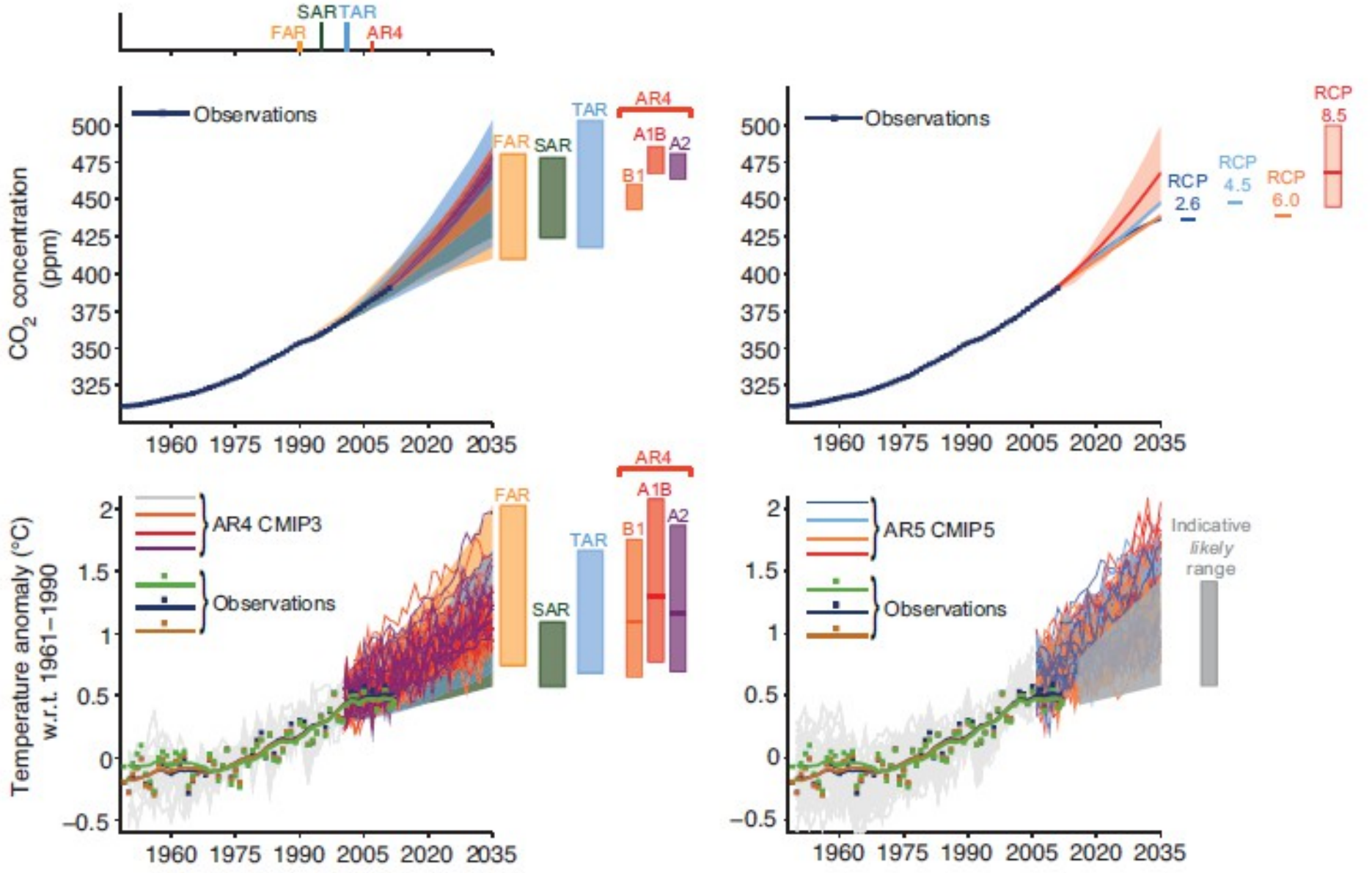

Fonte IPCC ARW5

# Simulazione delle forzanti sul clima futuro




Fonte IPCC ARW5

# Scenari di cambiamenti climatici per il XXI secolo



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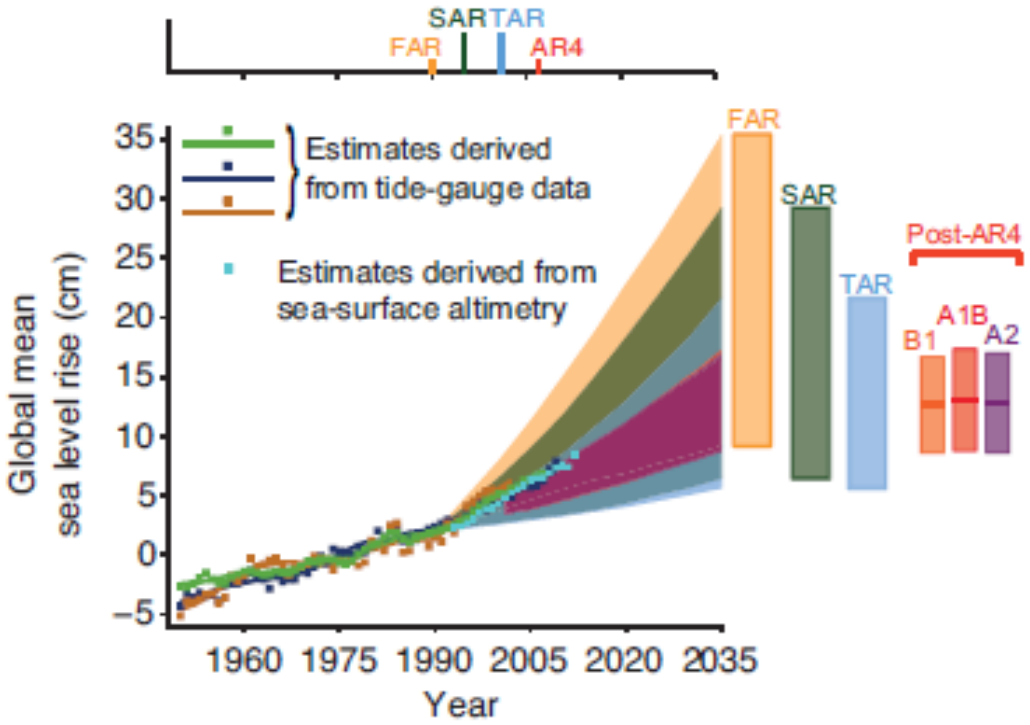
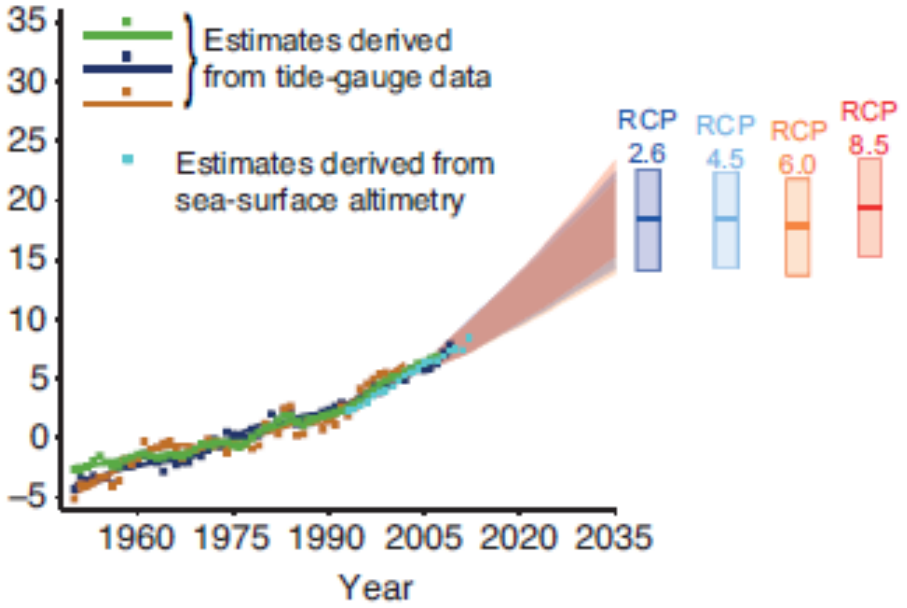
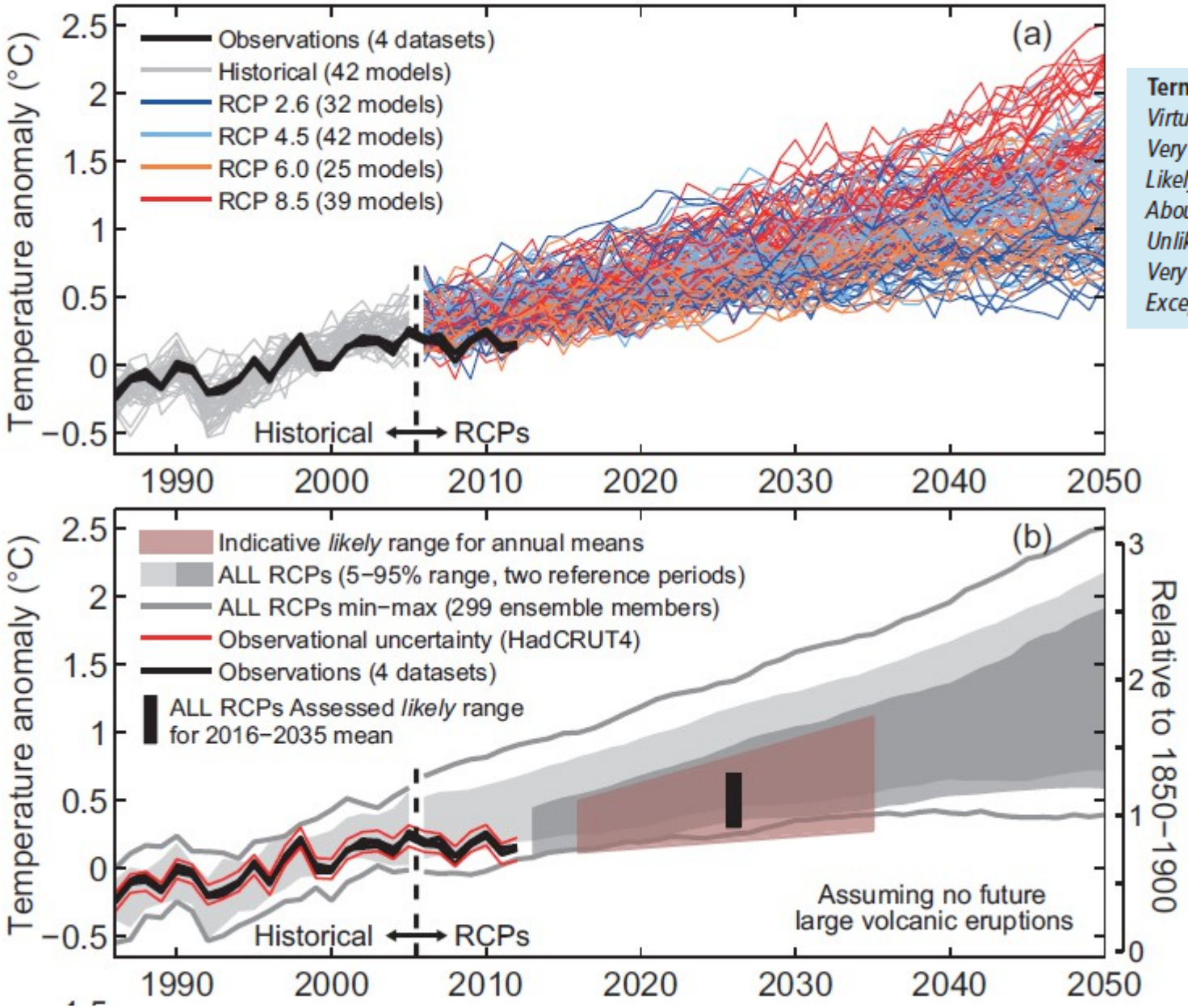


# Scenari di cambiamenti climatici per il XXI secolo – Valutazione incertezze

## Global mean temperature near-term projections relative to 1986–2005




| Term* | Likelihood of the outcome |
|---|---|
| *Virtually certain* | 99–100% probability |
| *Very likely* | 90–100% probability |
| *Likely* | 66–100% probability |
| *About as likely as not* | 33–66% probability |
| *Unlikely* | 0–33% probability |
| *Very unlikely* | 0–10% probability |
| *Exceptionally unlikely* | 0–1% probability |

# Bibliografia

[1] Earth's Climate – Past and Future (Second Edition), by William Ruddiman, 2008, W. H. Freeman and Company Biblioteca Tecnico Scientifica BS/04/M/0009

[2] Intergovernmental Panel on Climate Change - Fifth Assessment Report (AR5)- https://www.ipcc.ch/report/ar5/mindex.shtml