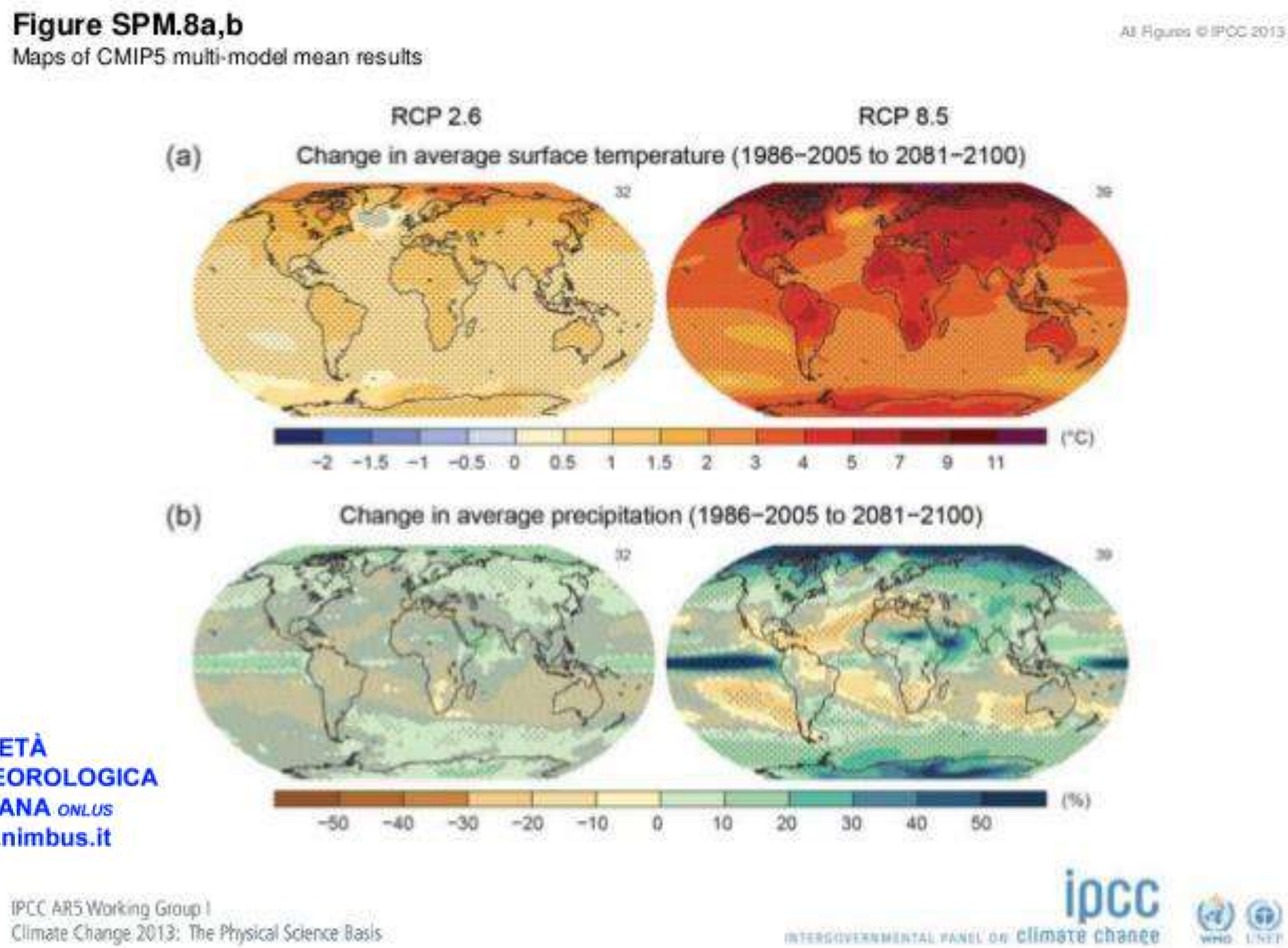
Gli scenari climatici del futuro

Luca Mercalli – Società Meteorologica Italiana
www.nimbus.it



SOCIETÀ METEOROLOGICA ITALIANA ONLUS
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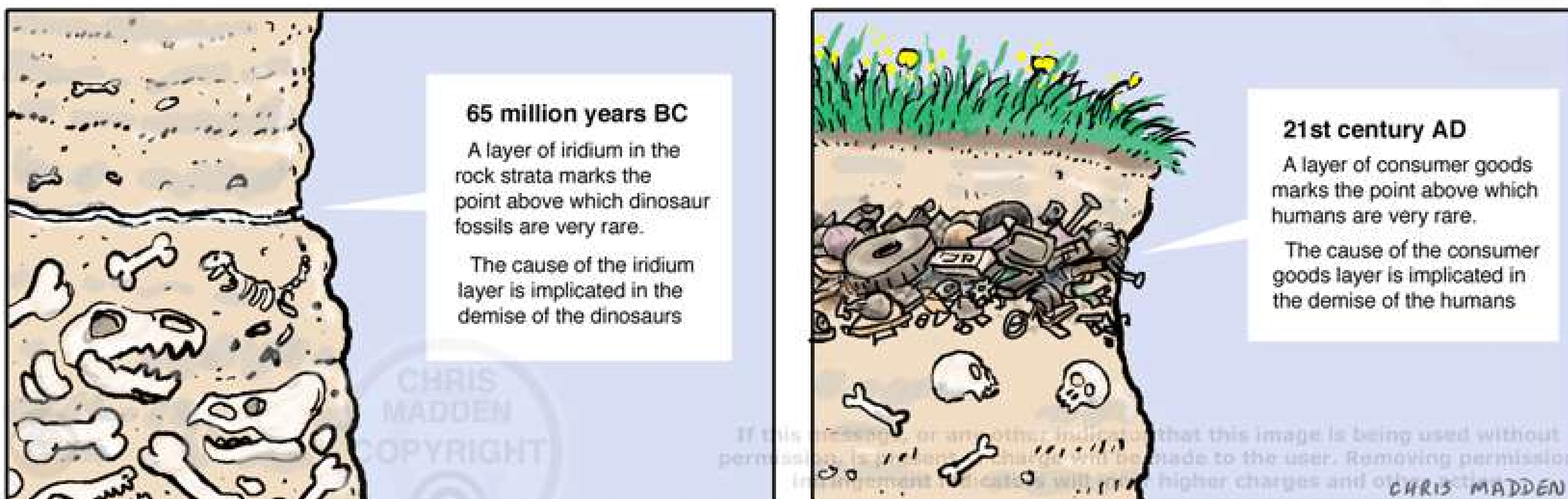
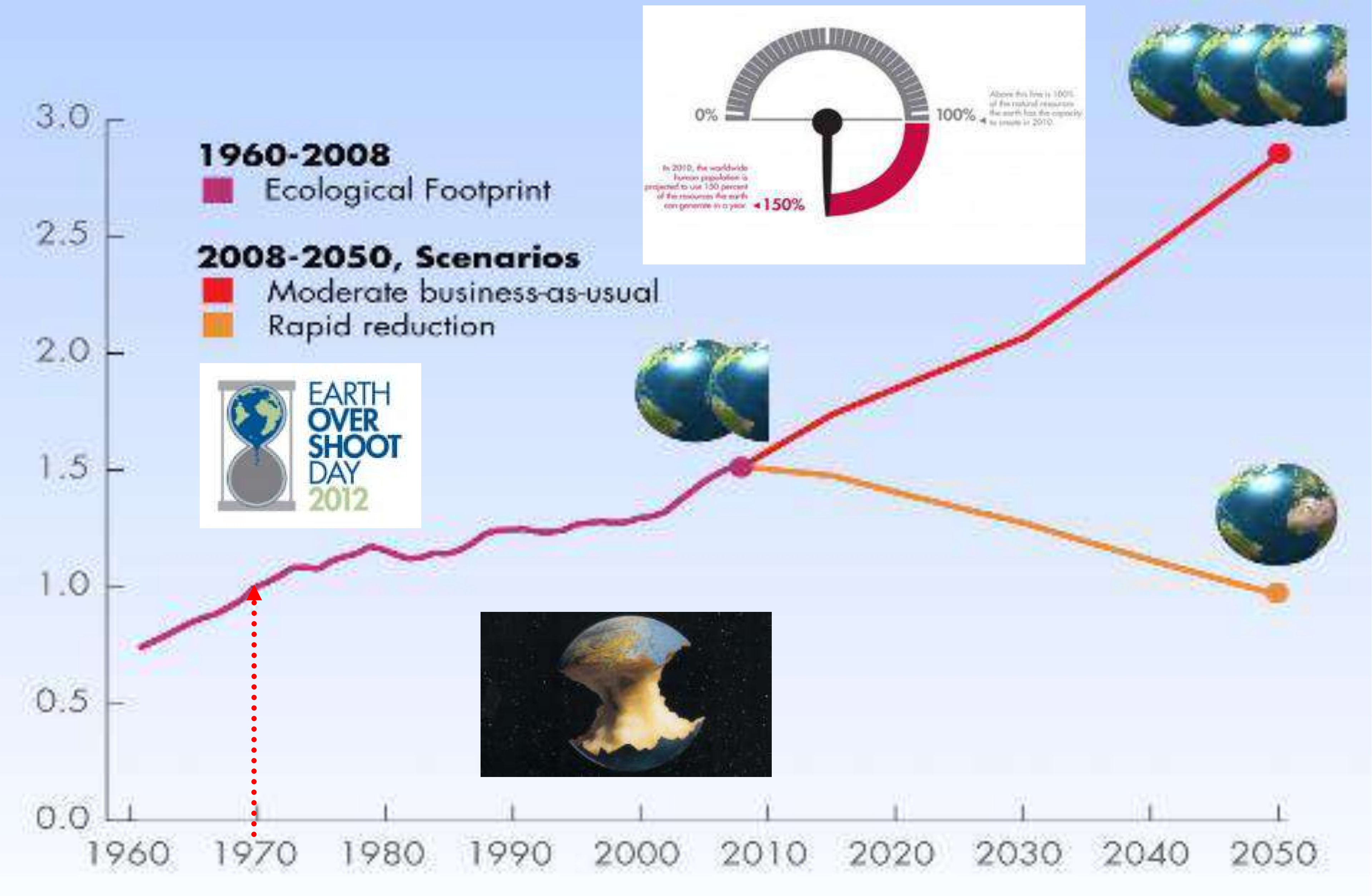
ANTHROPOCENE

approx. 1945 A.D. - present

A new geologic era with no precise start date. Marked by significant human impact on climate and ecosystems. Coined by Paul Crutzen. Rise of agriculture. Deforestation. Cement. Combustion of fossil fuels. Coal, oil and gas roused from the earth. Extraction and emission. Operation Crossroads vaporizes 70 acres of Bikini Atoll. Deep geologic repositories. Pacific Trash Vortex, a swirling gyre of marine litter and plastic. 6.7 billion humans + growing. Palo Verde Nuclear Power Plant. Hull-Rust-Mahoning open pit mine. Three Gorges Dam. Fresh Kills Landfill. Las Vegas. Dubai.

LESSONS FROM THE FOSSIL RECORD





y-axis: number of planet earths, x-axis: years

Rockstrom et al., 2009

nature Vol 461|24 September 2009

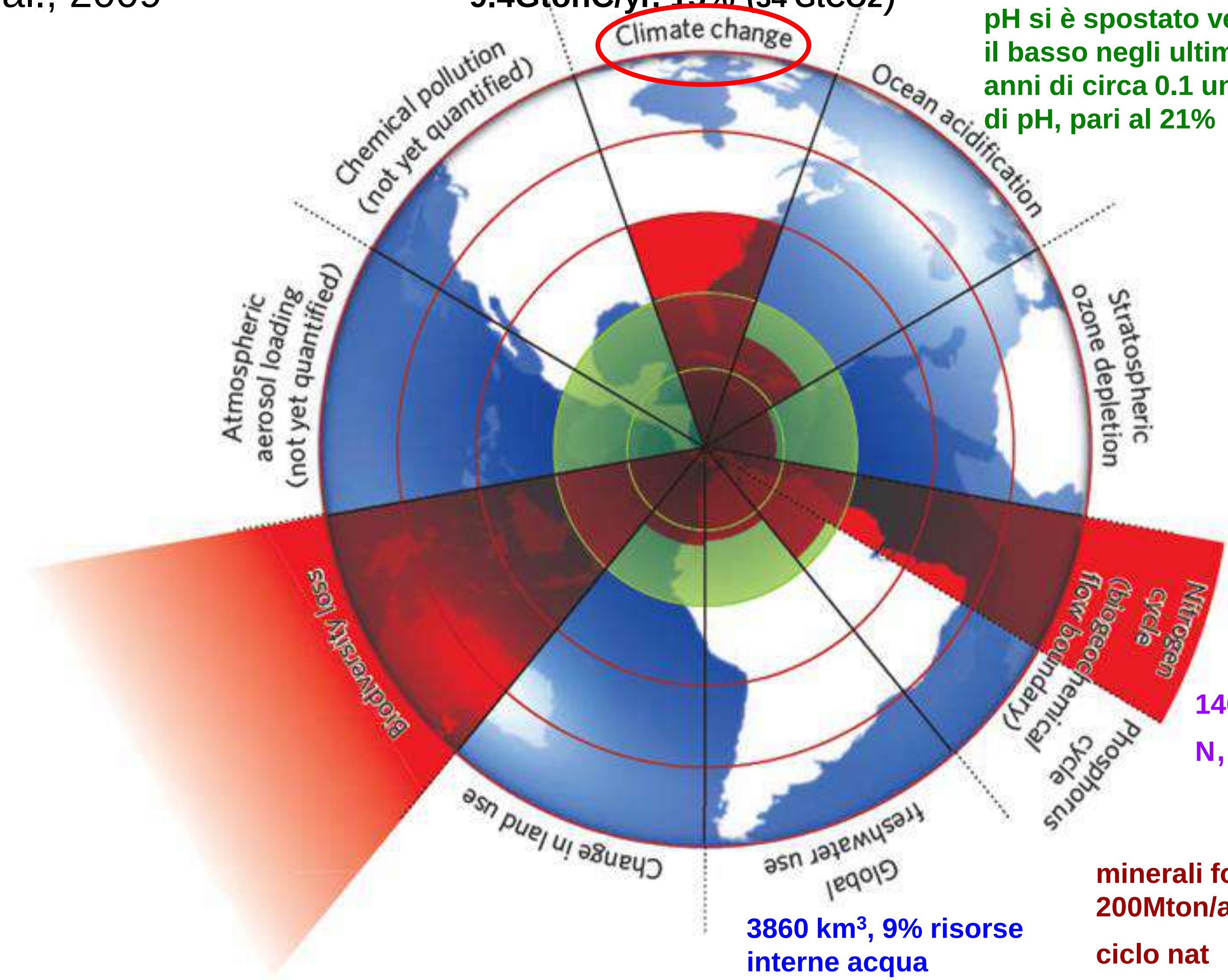
FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

9.4GtonC/yr, 15% (34 $GtCO_2$)

pH si è spostato verso il basso negli ultimi 250 anni di circa 0.1 unità di pH, pari al 21%



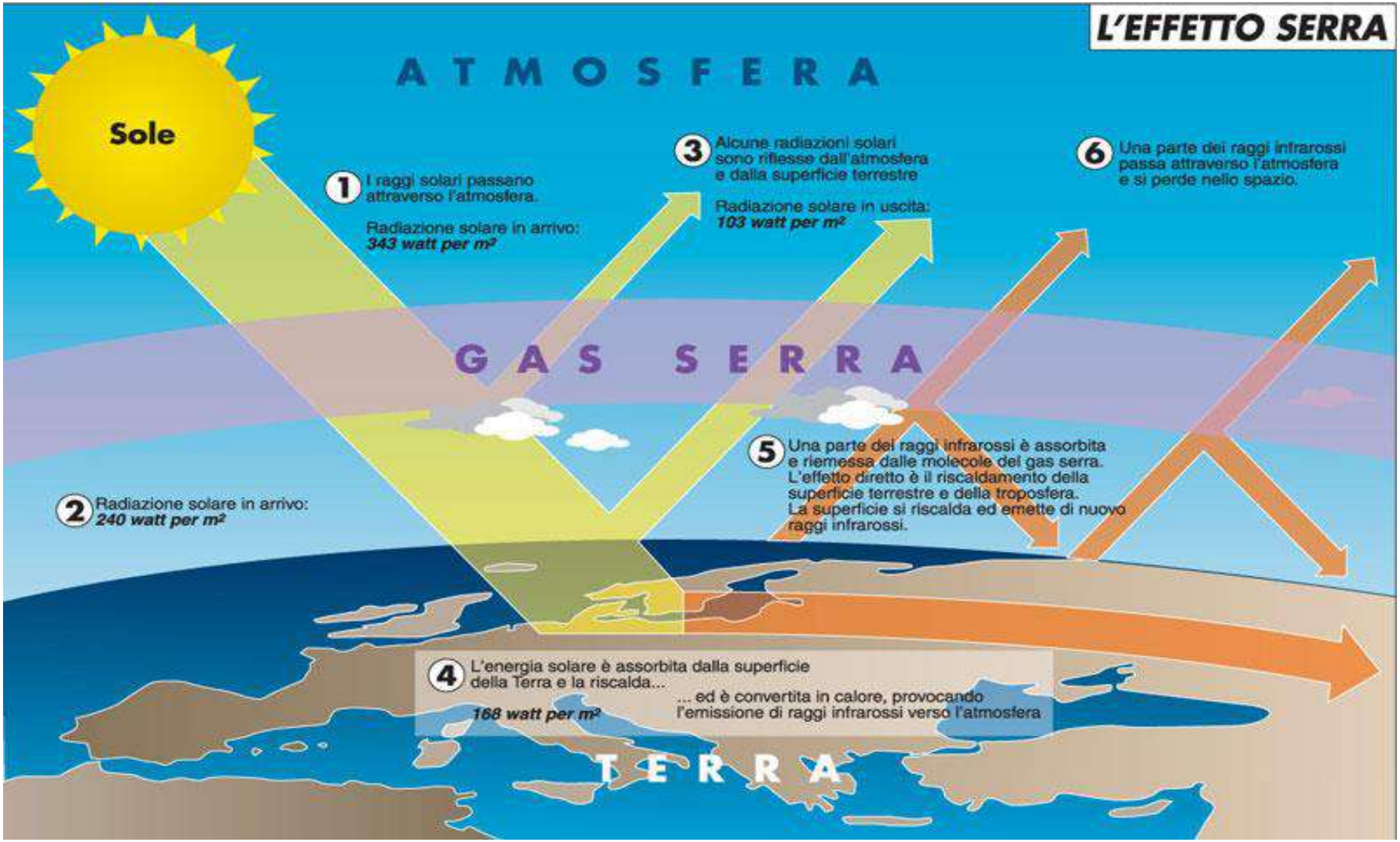
140Mton N, 100%

minerali fosfatici 200Mton/anno; 1/7 ciclo nat

3860 km^3, 9% risorse interne acqua (AQUASTAT)

Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

Terra senza effetto serra -18 °C
Con effetto serra naturale +15 °C



PHILOSOPHICAL MAGAZINE AND JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

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

Svante August Arrhenius
(Nobel prize, Chemistry,1903)

Developed the hothouse theory for CO_2 in 1896, and in 1905 predicted that raising CO_2 content of the atmosphere would cause an increase in mean global temperature similar in magnitude to modern predictions

Endeavour Vol. xxx No. x

ScienceDirect

CO_2, the greenhouse effect and global warming: from the pioneering work of Arrhenius and Callendar to today's Earth System Models

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Climate warming during the course of the twenty-first century is projected to be between 1.0 and 3.7 °C depending on future greenhouse gas emissions, based on the ensemble-mean results of state-of-the-art Earth System Models (ESMs). Just how reliable are these projections, given the complexity of the climate system? The early history of climate research provides insight into the understanding and science needed to answer this question. We examine the mathematical quantifications of planetary energy budget developed by Svante Arrhenius (1859–1927) and Guy Stewart Callendar (1898–1964) and construct an empirical approximation of the latter, which we show to be successful at retrospectively predicting global warming over the course of the twentieth century. This approximation is then used to calculate warming in response to increasing atmospheric greenhouse gases during the twenty-first century, projecting a temperature increase at the lower bound of results generated by an ensemble of ESMs (as presented in the latest assessment by the Intergovernmental Panel on Climate Change). This result can be interpreted as follows. The climate system is conceptually complex but has at its heart the physical laws of radiative transfer. This basic, or "core" physics is relatively straightforward to compute mathematically, as exemplified by Callendar's calculations, leading to quantitatively robust projections of baseline warming. The ESMs include not only the physical core but also climate feedbacks that introduce uncertainty into the projections in terms of magnitude, but not sign: positive (amplification of warming). As such, the projections of end-of-century global warming by ESMs are fundamentally trustworthy: quantitatively robust baseline warming based on the well-understood physics of radiative transfer, with extra warming due to climate feedbacks. These projections thus provide a compelling case that global climate will continue to undergo significant warming in response to ongoing emissions of CO_2 and other greenhouse gases to the atmosphere.

Introduction

Climate change is a major risk facing mankind. At the United Nations Climate Change Conference held in Paris at the end of last year, 195 countries agreed on a plan to reduce emissions of CO_2 and other greenhouse gases, aiming to limit global temperature increase to well below 2 °C (relative to pre-industrial climate, meaning a future warming of less than 1.4 °C because temperature had already increased by 0.6 °C by the end of the twentieth century). The link between CO_2 and climate warming has caught the attention of scientists and politicians, as well as the general public, via the well-known "greenhouse effect" (Figure 1). Solar radiation passes largely unhindered through the atmosphere, heating the Earth's surface. In turn, energy is re-emitted as infrared, much of which is absorbed by CO_2 and water vapour in the atmosphere, which thus acts as a blanket surrounding the Earth. Without this natural greenhouse effect, the average surface temperature would plummet to about −21 °C,[1] rather less pleasant than the 14 °C experienced today.

The concentration of CO_2 in the atmosphere is increasing year on year as we burn fossil fuels, which enhances the natural greenhouse effect and warms the planet. To what extent, then, must CO_2 emissions be kept under control in order to restrict global temperature rise to within 2 °C? The projections of complex Earth System Models (ESMs) provide quantitative answers to this question. Run on supercomputers, these models integrate the many processes taking place in the atmosphere, on land and in the ocean. According to the Intergovernmental Panel on Climate Change (IPCC), the latest results of these models indicate

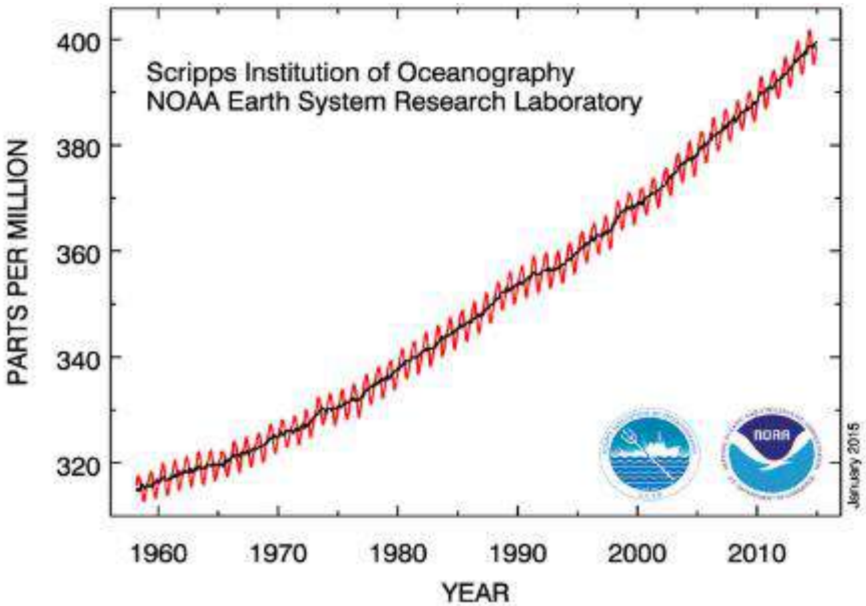
*Corresponding author. Anderson, T.R.
Hawkins, E. Jones, P.D.

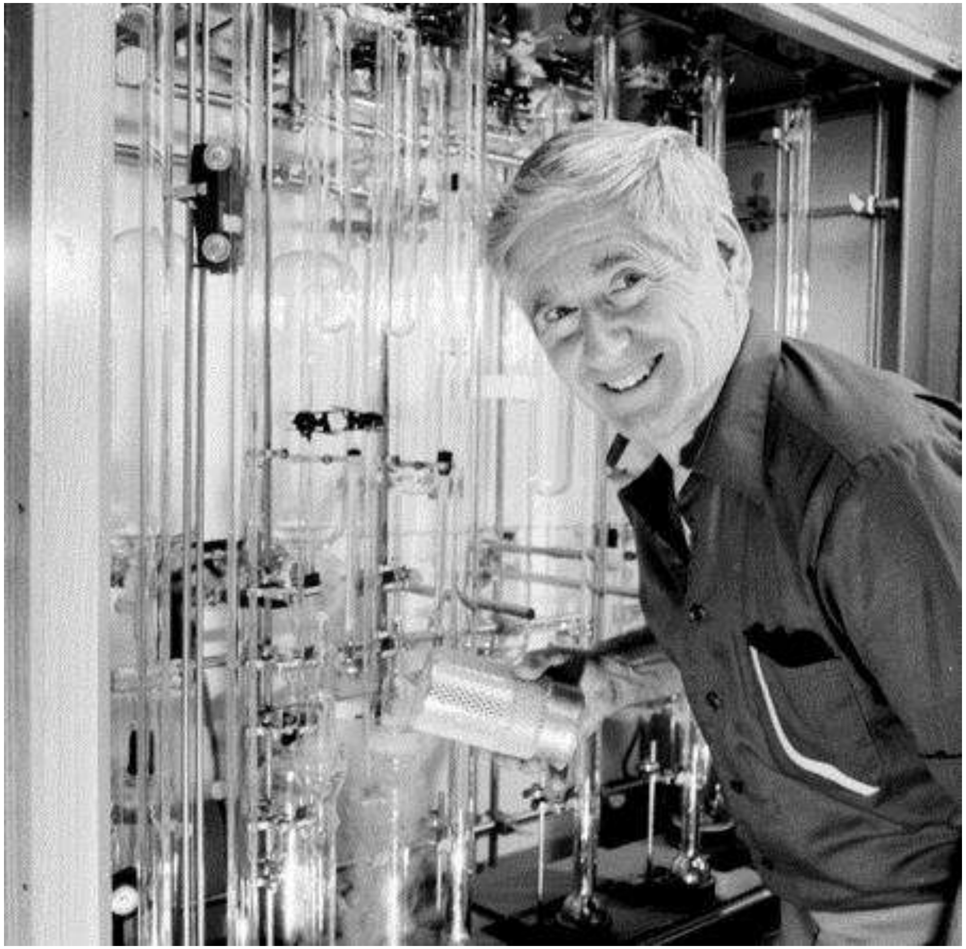
Keywords: Greenhouse effect; Global warming; Earth System Models; Arrhenius; Callendar.

[1] Andrew A. Lacis, Gavin A. Schmidt, David Rind, and Reto A. Ruedy, "Atmospheric CO_2: Principal Control Knob Governing Earth's Temperature," *Science* 330 (2010): 356–59.

Charles David Keeling's first observations, 1958-60

- Unequivocal evidence that CO_2 concentrations are rising steadily





Carbon Dioxide and Climate: A Scientific Assessment

Report to the National Academy of Sciences
Jule G. Charney and co-authors
1979

When it is assumed that the CO2 content of the atmosphere is doubled and statistical thermal equilibrium is achieved, the more realistic of the modeling efforts predict a global surface warming of between 2°C and 3.5 °C, with greater increases at high latitudes.

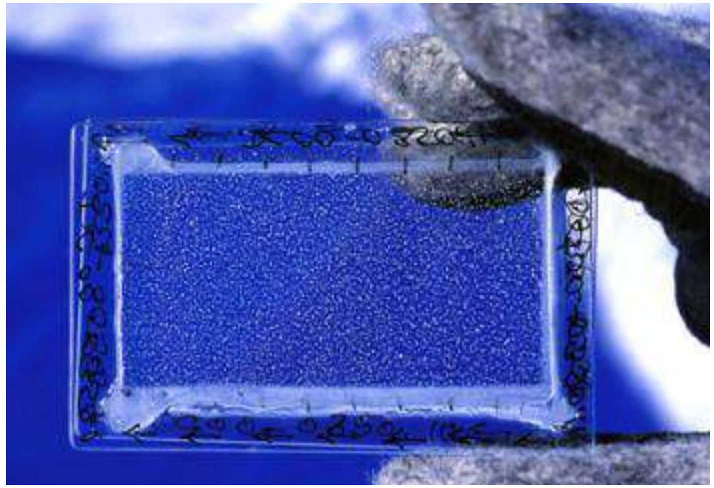
- Oceans "could delay the estimated warming for several decades"
- "We may not be given a warning until the CO_2 loading is such that an appreciable climate change is inevitable."

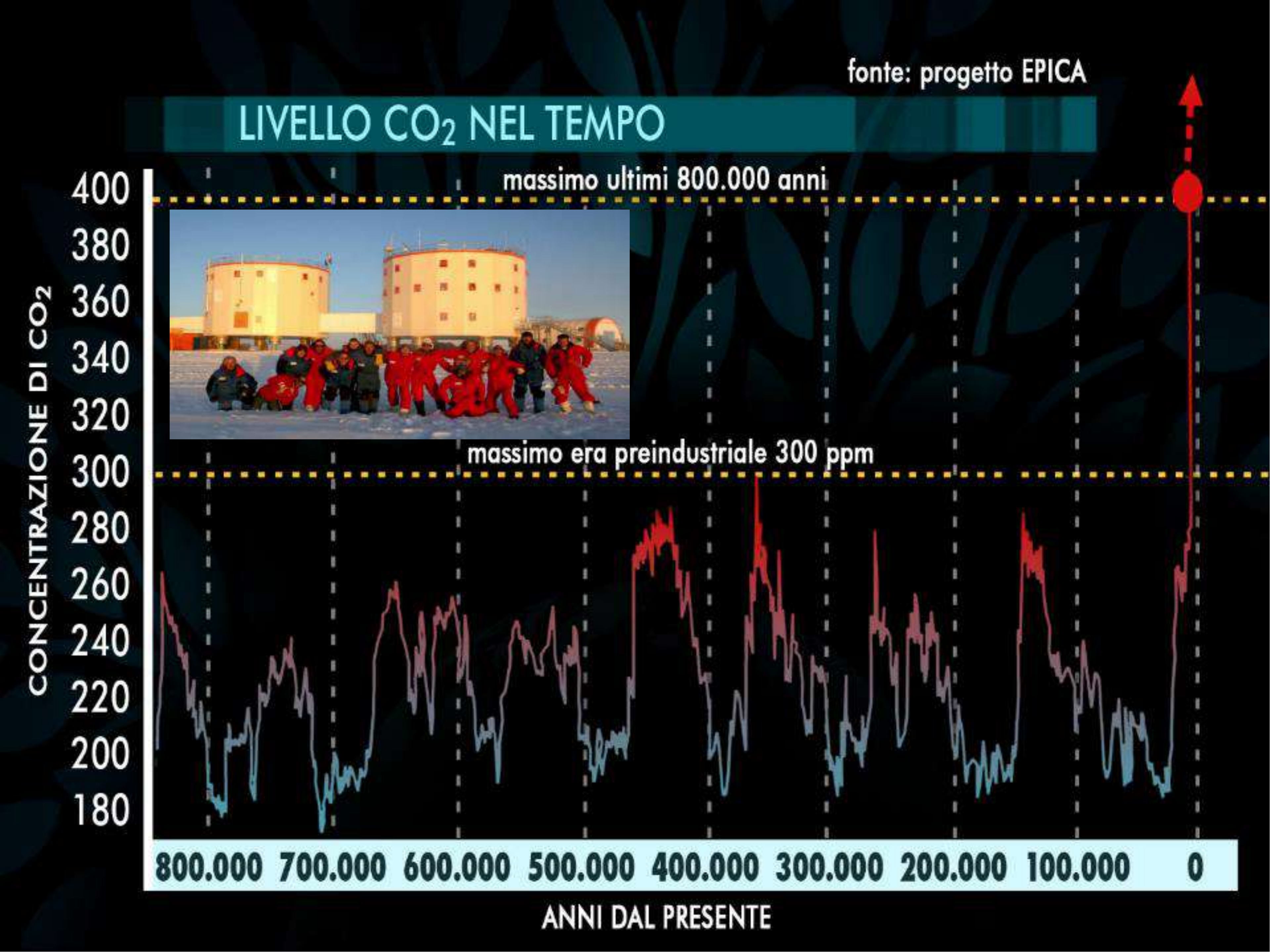
Progetto EPICA

(European Project for Ice Coring in Antarctica)

Stazione italo-francese Concordia, a Dome C - Antartide

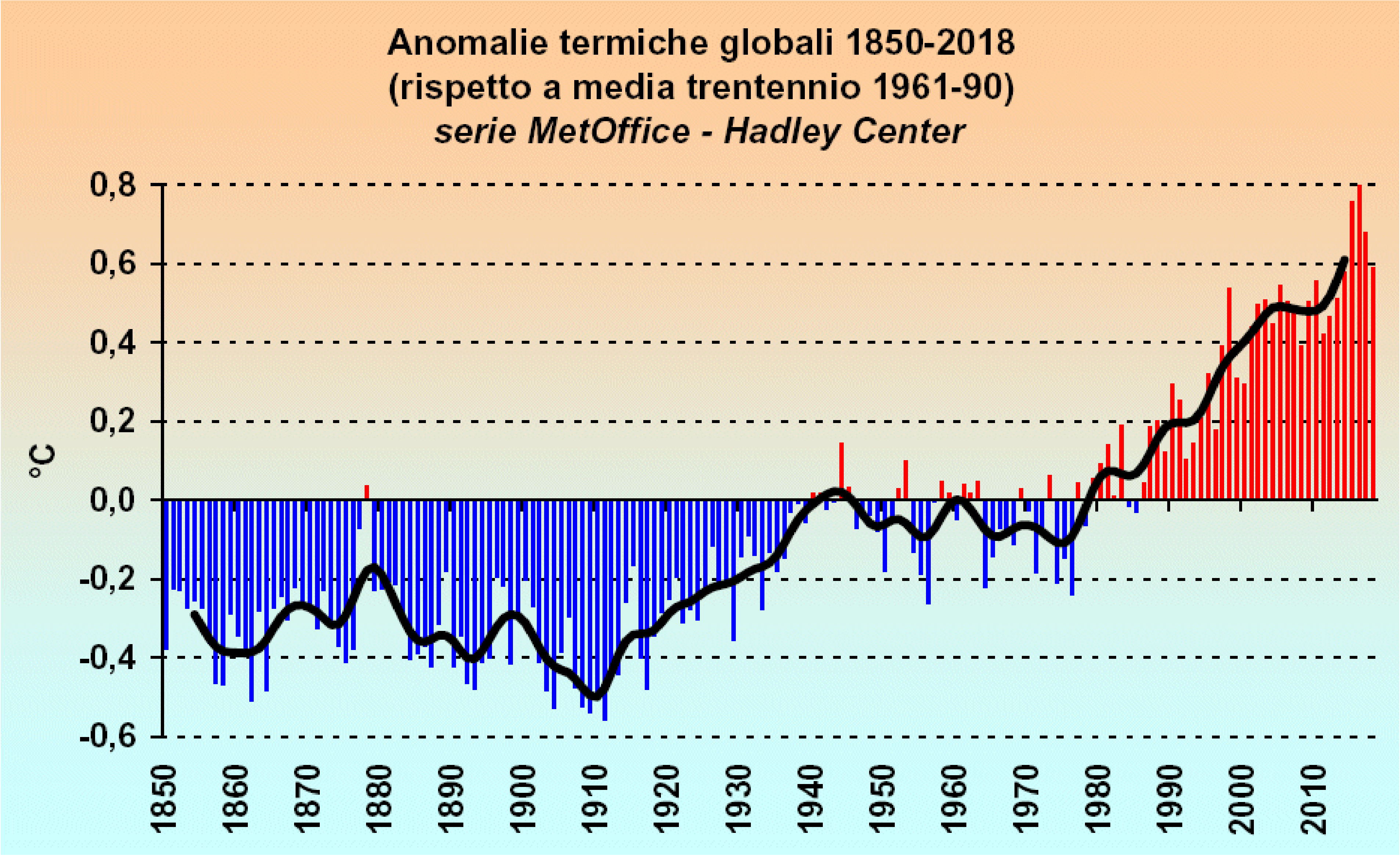
L'analisi delle bolle d'aria sigillate nel ghiaccio permette di ricostruire le concentrazioni storiche di CO_2 e metano

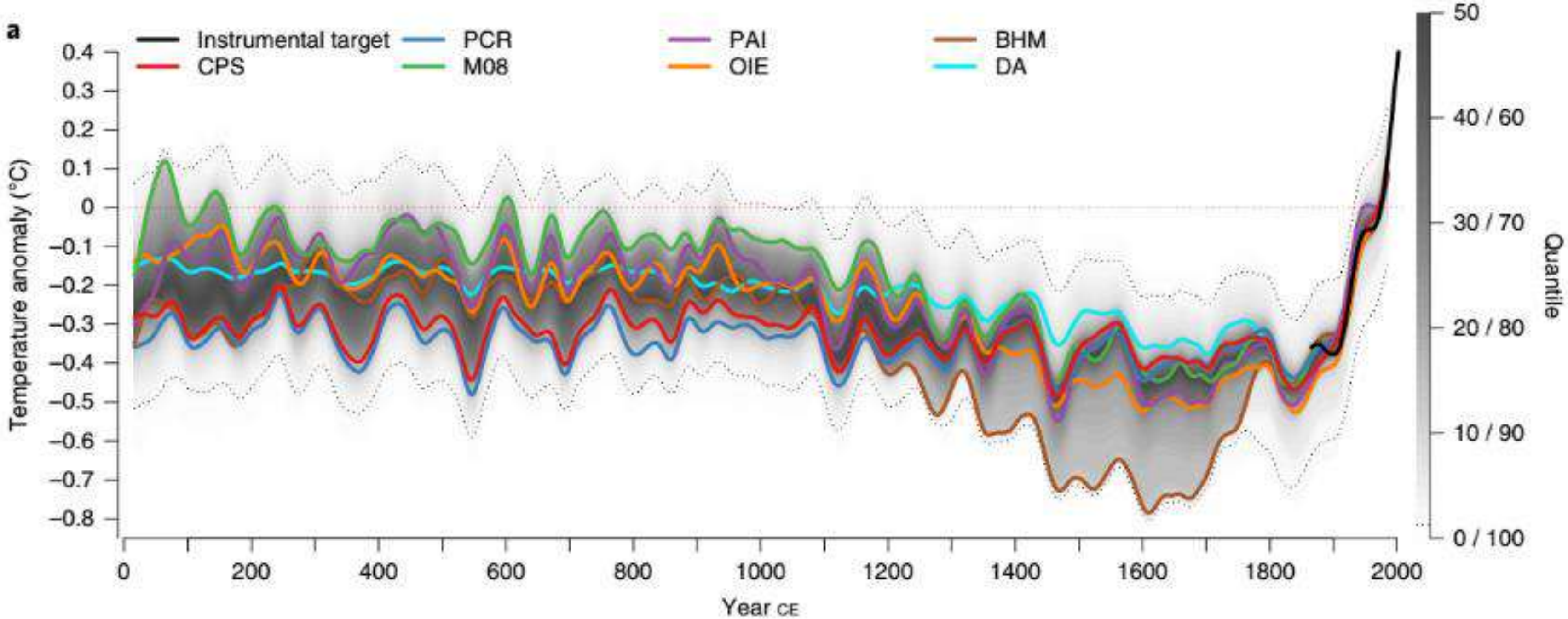




fonte: progetto EPICA
LIVELLO CO_2 NEL TEMPO
massimo ultimi 800.000 anni
massimo era preindustriale 300 ppm
CONCENTRAZIONE DI CO_2
400
380
360
340
320
300
280
260
240
220
200
180
800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
0
ANNI DAL PRESENTE

Temperatura media globale: +1°C in più nell'ultimo secolo



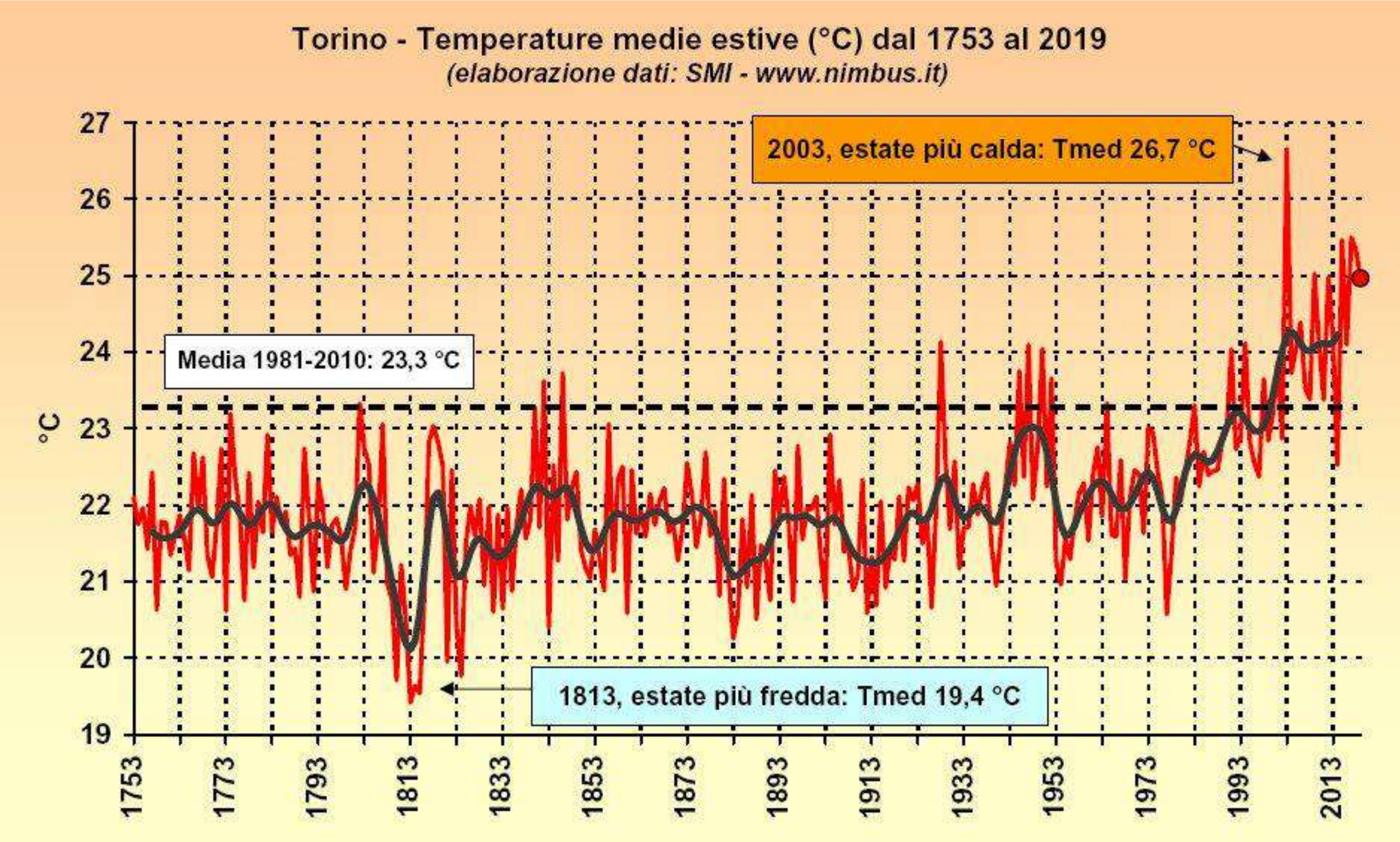


nature geoscience
ARTICLES
https://doi.org/10.1038/s41561-019-0400-0

Consistent multidecadal variability in global temperature reconstructions and simulations over the Common Era

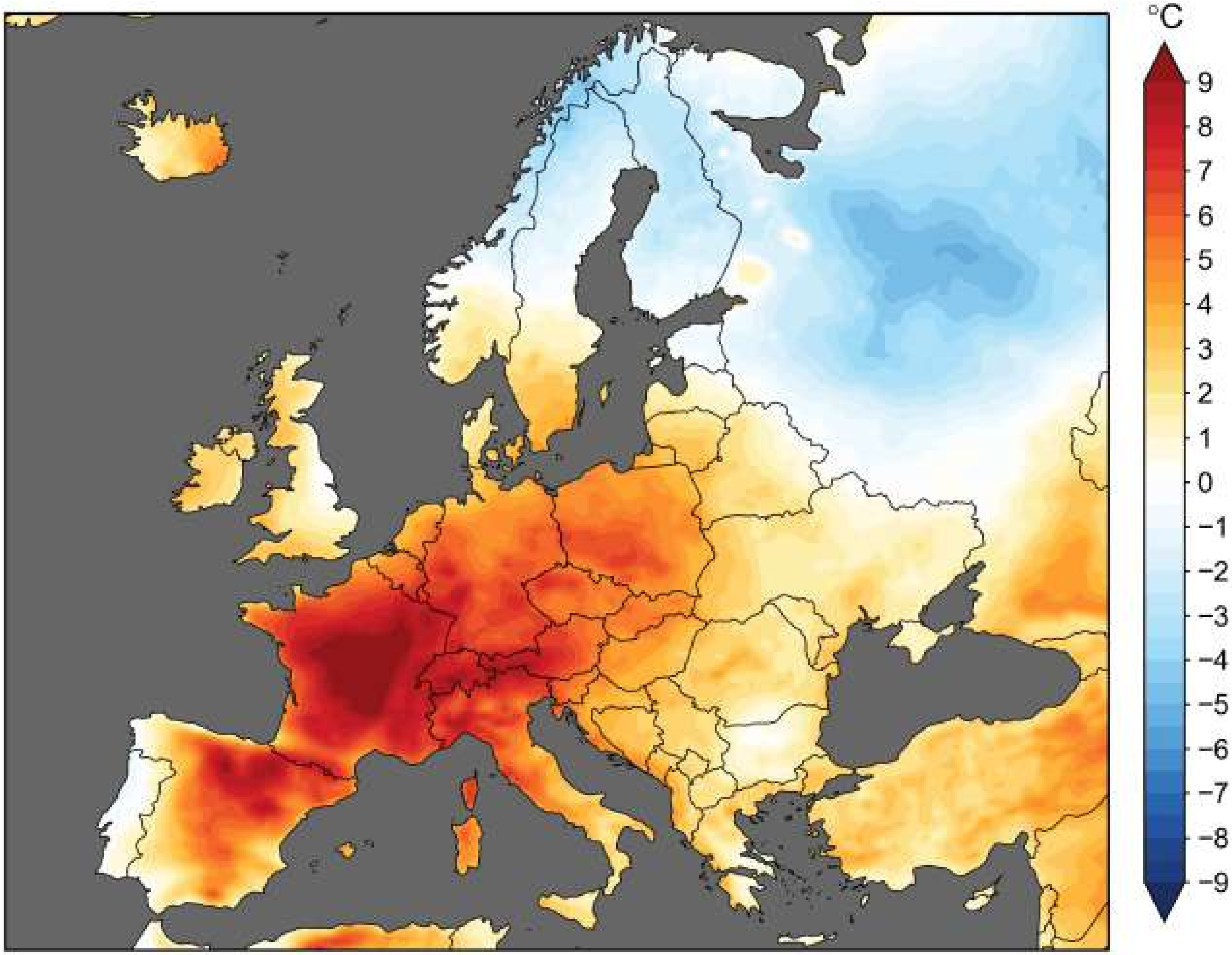
PAGES 2k Consortium*

Multidecadal surface temperature changes may be forced by natural as well as anthropogenic factors, or arise unforced from the climate system. Distinguishing these factors is essential for estimating sensitivity to multiple climatic forcings and the amplitude of the unforced variability. Here we present 2,000-year-long global mean temperature reconstructions using seven different statistical methods that draw from a global collection of temperature-sensitive palaeoclimate records. Our reconstructions display synchronous multidecadal temperature fluctuations that are coherent with one another and with fully forced millennial model simulations from the Coupled Model Intercomparison Project Phase 5 across the Common Era. A substantial portion of pre-industrial (1300–1800 CE) variability at multidecadal timescales is attributed to volcanic aerosol forcing. Reconstructions and simulations qualitatively agree on the amplitude of the unforced global mean multidecadal temperature variability, thereby increasing confidence in future projections of climate change on these timescales. The largest warming trends at timescales of 20 years and longer occur during the second half of the twentieth century, highlighting the unusual character of the warming in recent decades.



9 su 10 delle estati più calde sono successive al 2002

Average 2m temperature anomaly for 25-29 June 2019



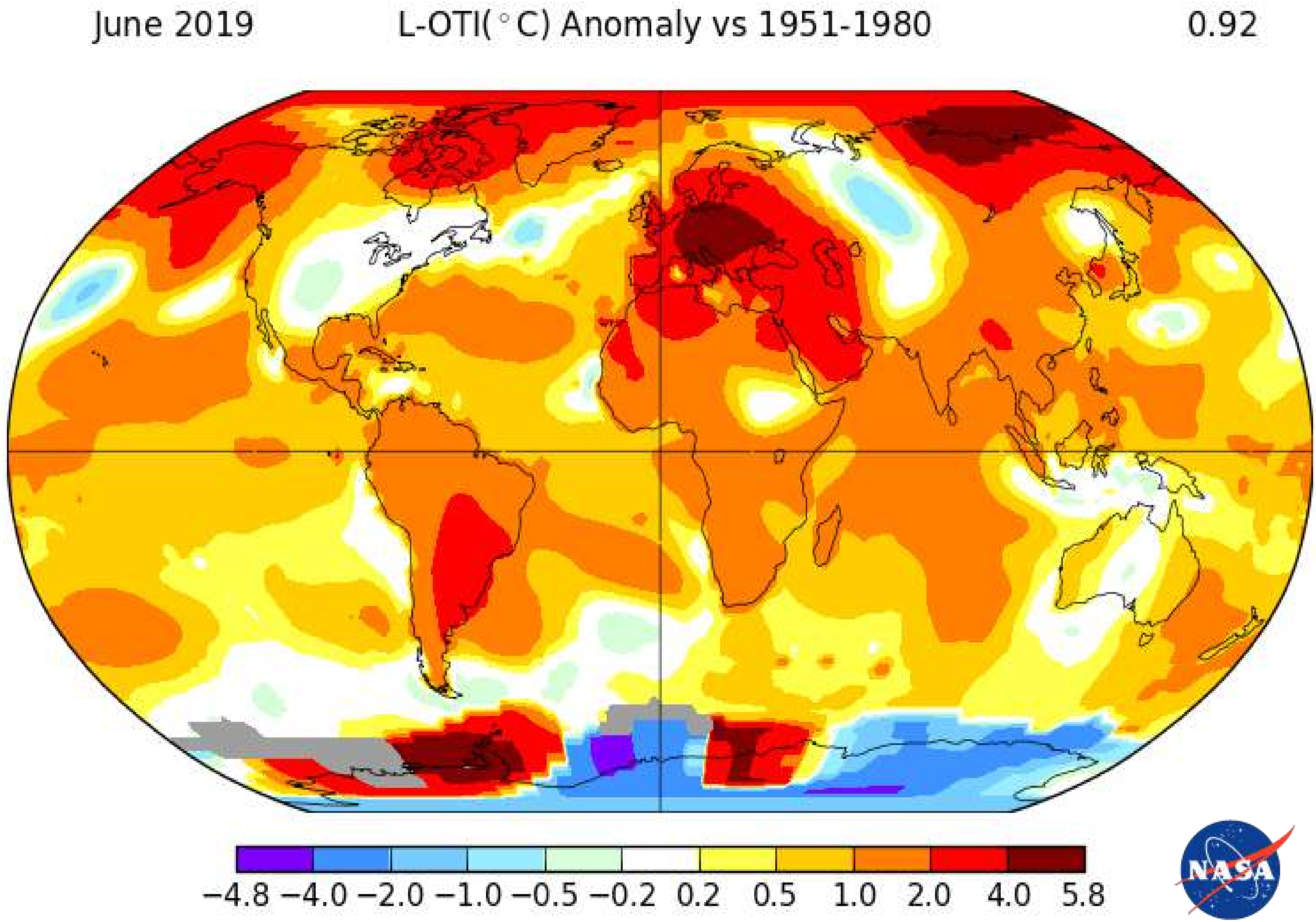
Giugno 2019 è risultato in Europa il **più caldo in assoluto** mai registrato. Mediamente anomalie dell'ordine dei 2°C rispetto al periodo 1981-2010, ma alcune aree, come Francia, Svizzera, Germania e Nord Italia, hanno fatto registrare anomalie anche di 6-10°C nei 5 giorni più caldi dal 25 al 29 giugno.

European Commission

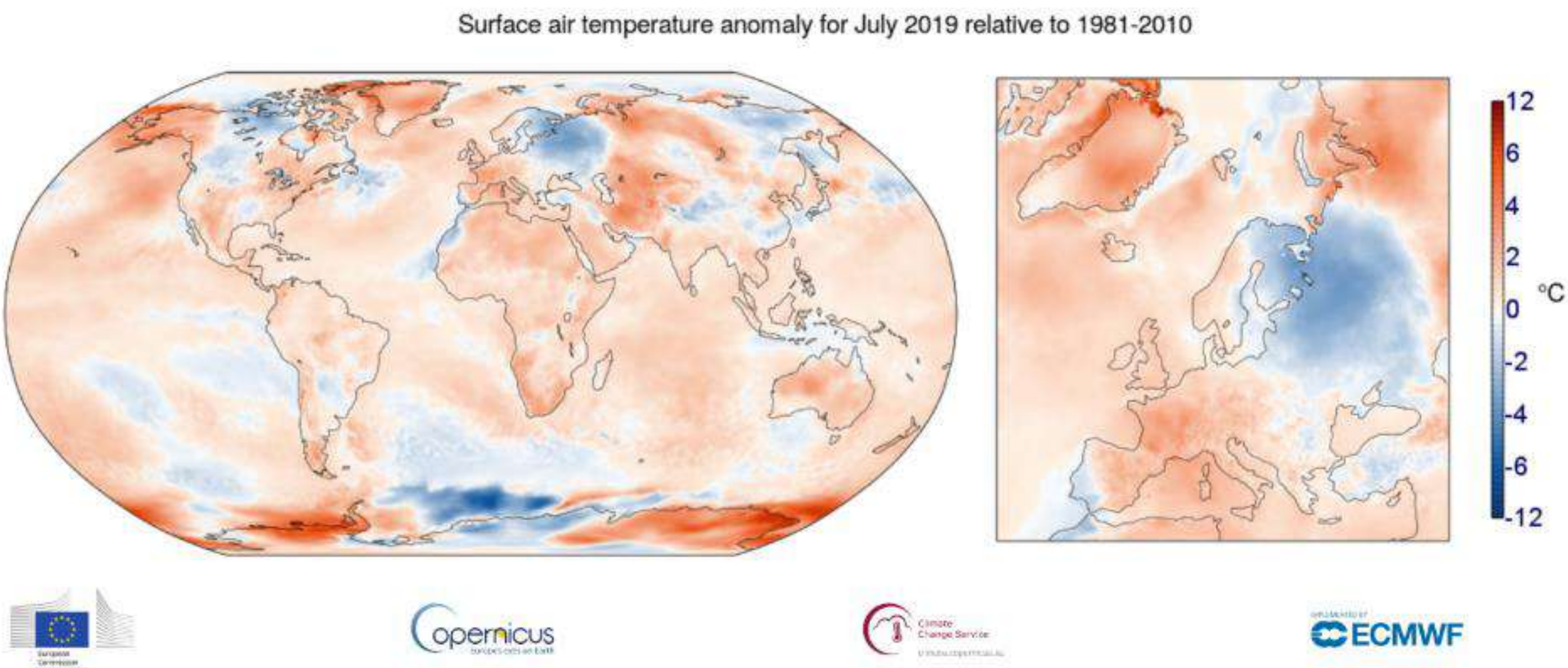
Copernicus
Europe's eyes on Earth

Climate Change Service
climate.copernicus.eu

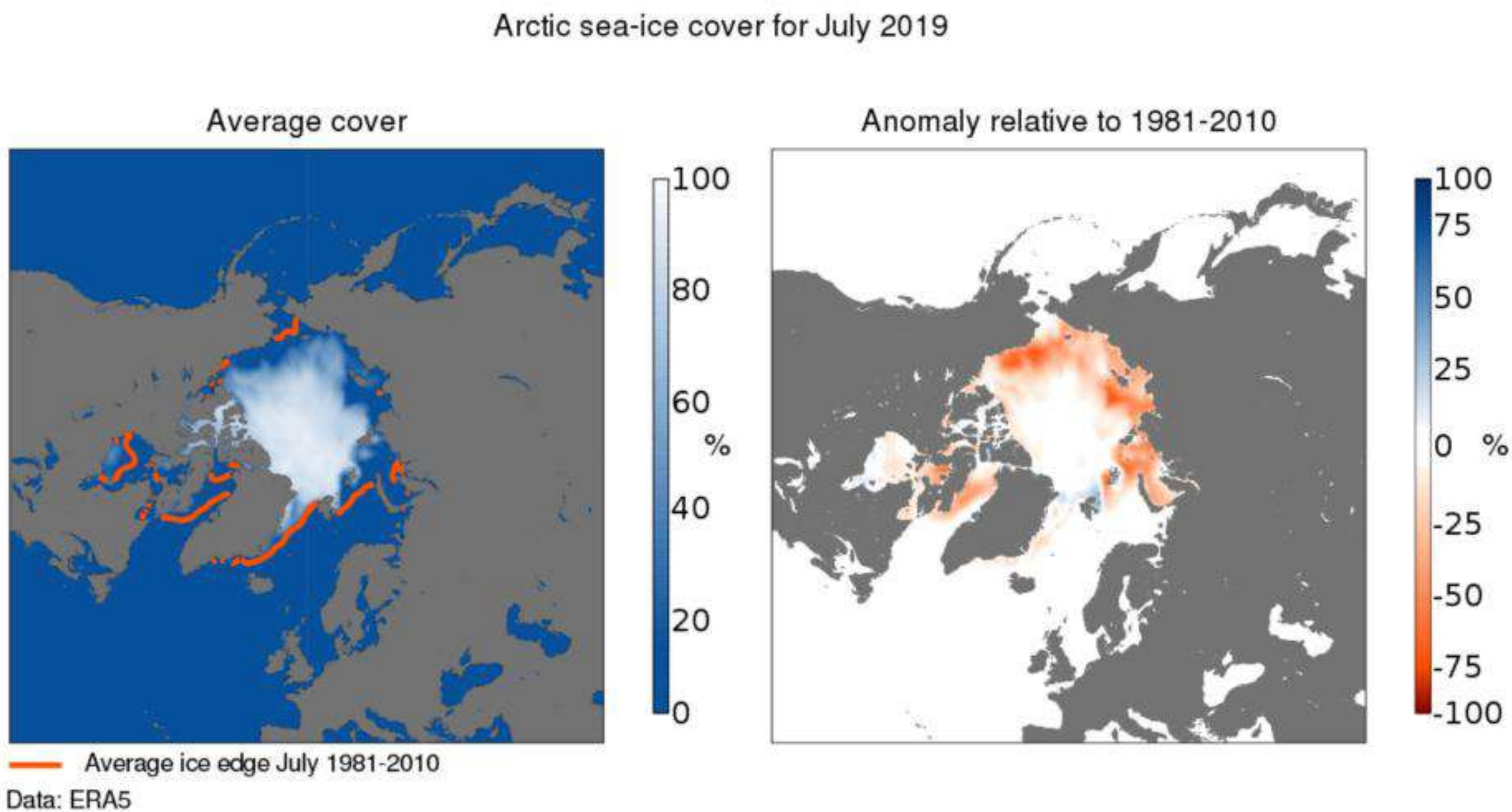
IMPLEMENTED BY ECMWF

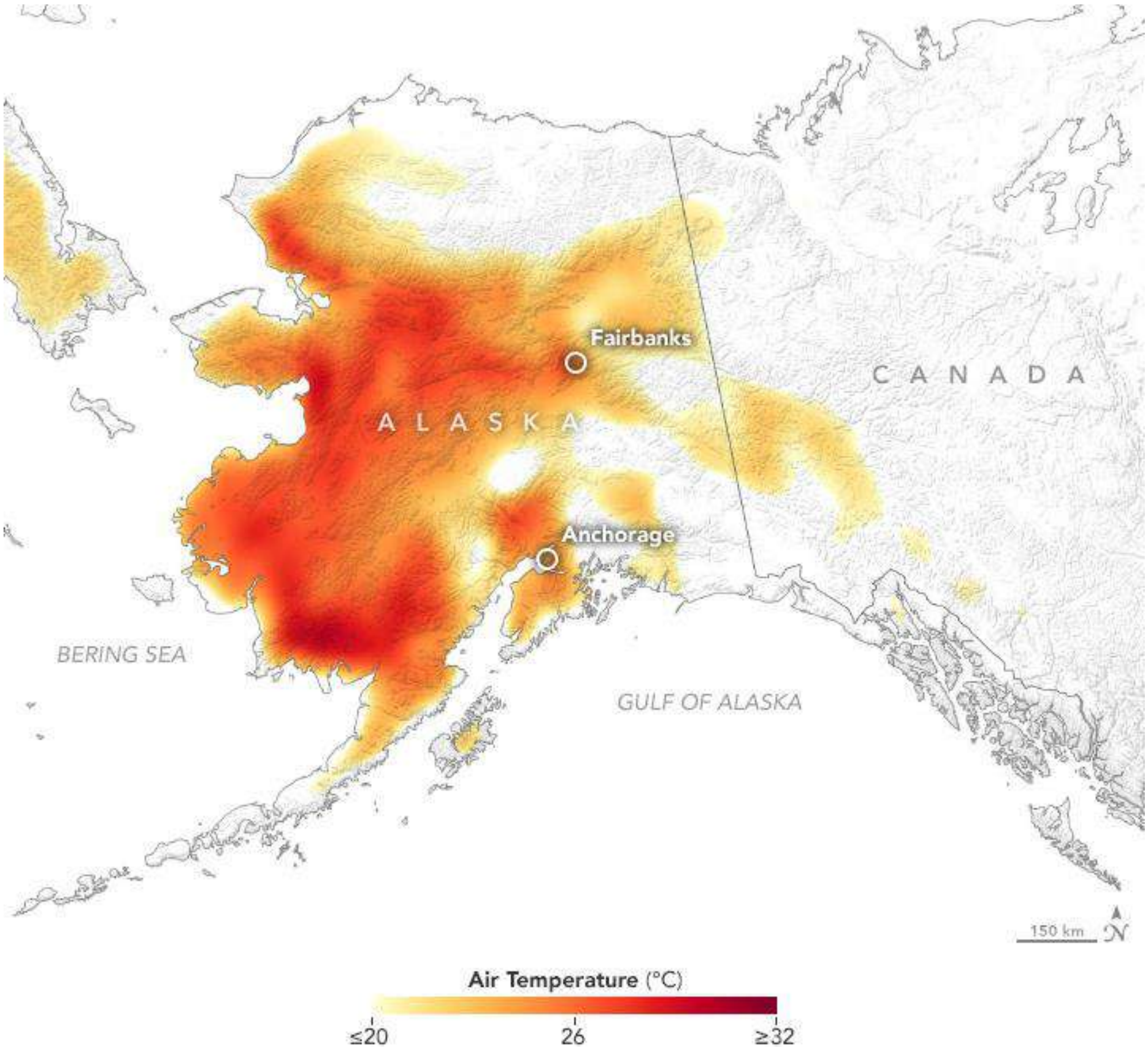

June 2019
L-OTI(°C) Anomaly vs 1951-1980
0.92
−4.8 −4.0 −2.0 −1.0 −0.5 −0.2 0.2 0.5 1.0 2.0 4.0 5.8
NASA

Luglio 2019: il mese più caldo della storia meteorologica terrestre



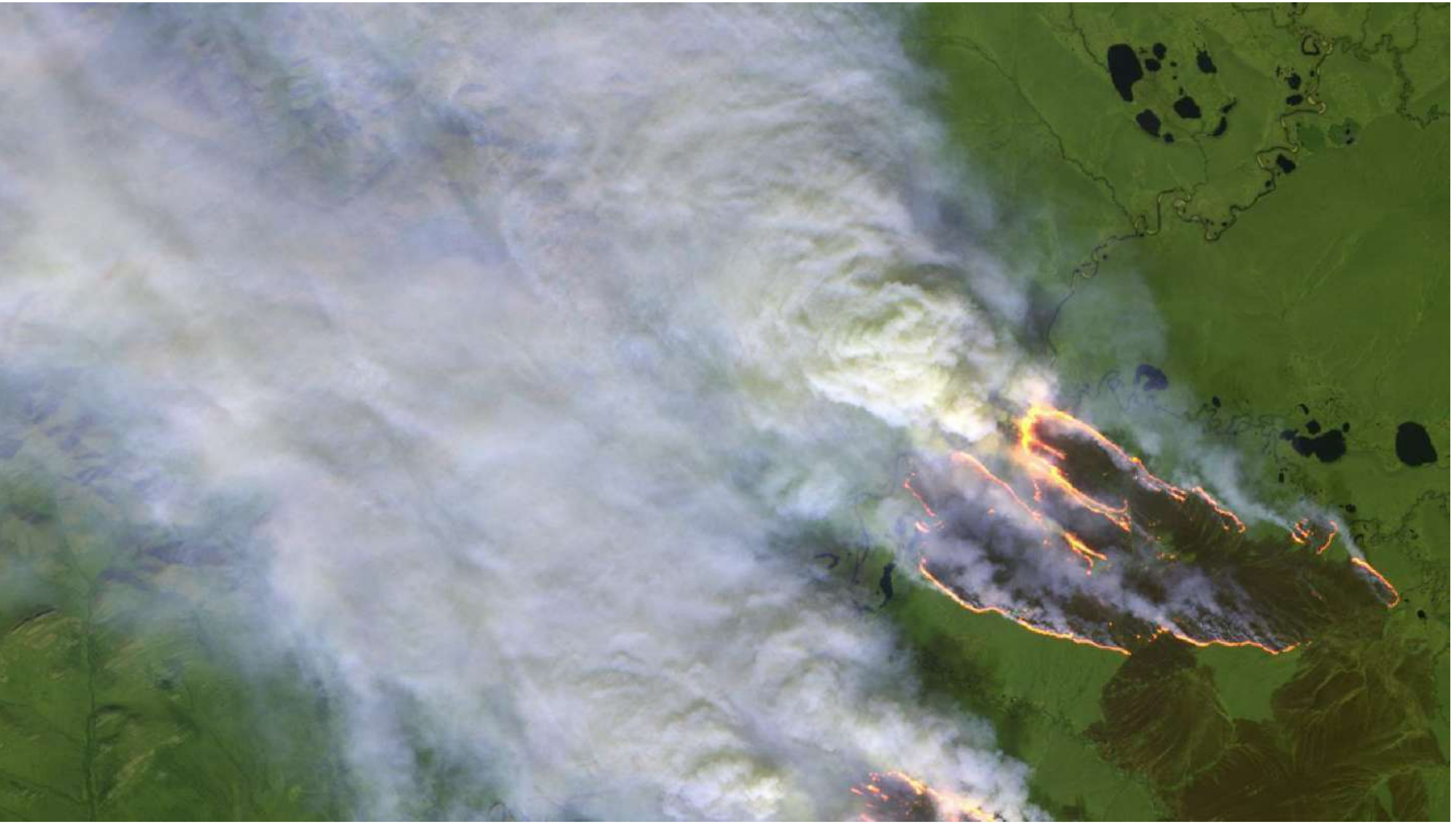
Banchisa polare ai minimi





Record
32°C
Alaska
4 lug
2019

Epocali incendi in Siberia



1897
(f. Druetti)

2005
(f. L. Mercalli)

2015
(f. S. Jobard)

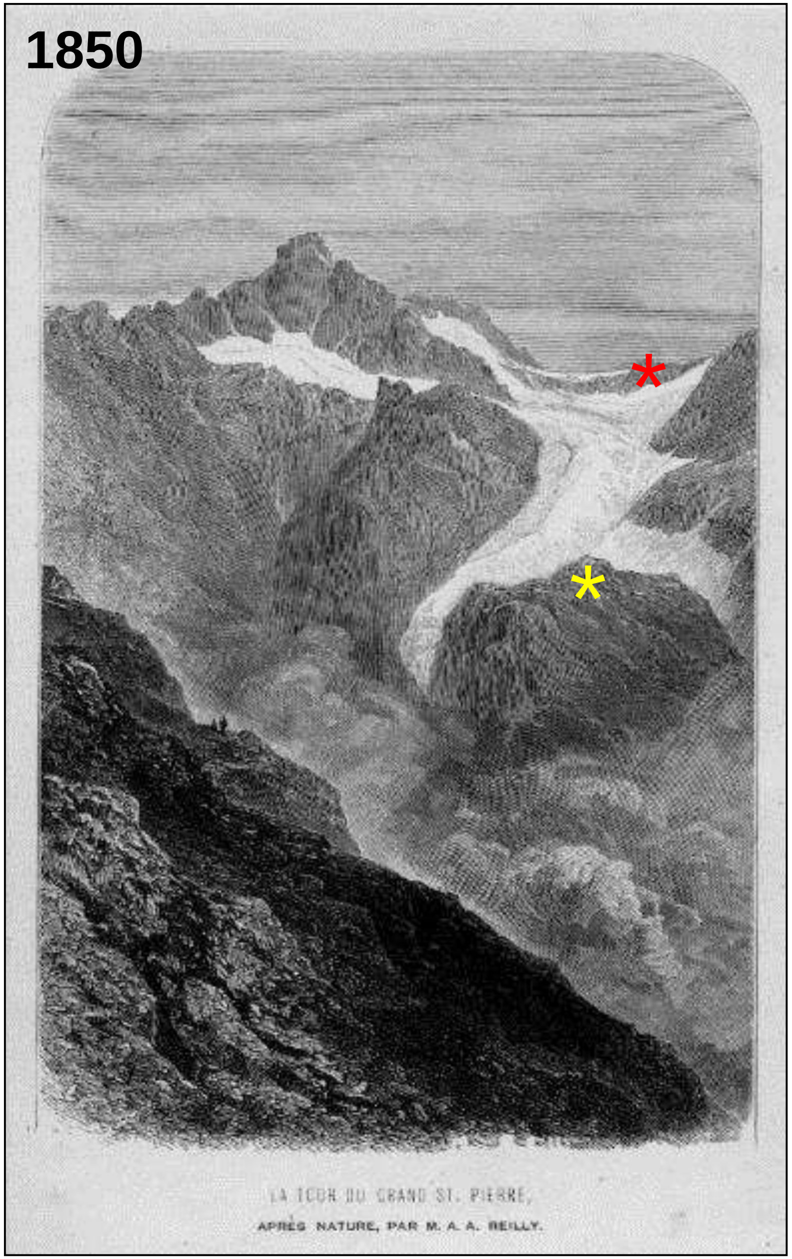
Ghiacciaio Pré de Bar (Monte Bianco):

ritiro della fronte di oltre 800 m dal 1897 al 2015

I ghiacciai alpini si sono ridotti di oltre il 50% in un secolo

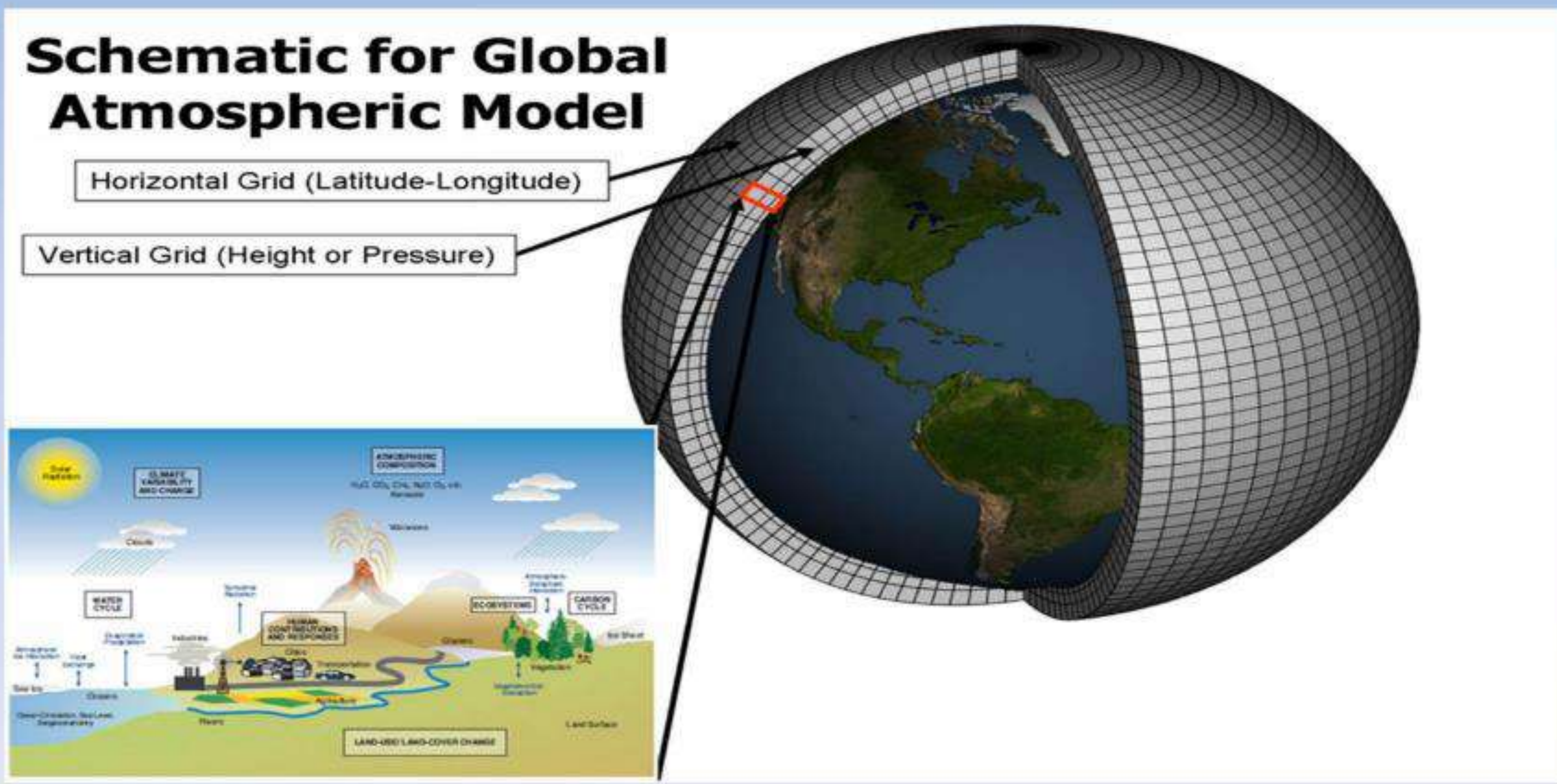
Ghiacciaio
Meridionale del
Sabbione
(Ossola)
dalla diga.

Regresso frontale
circa 1200 m.

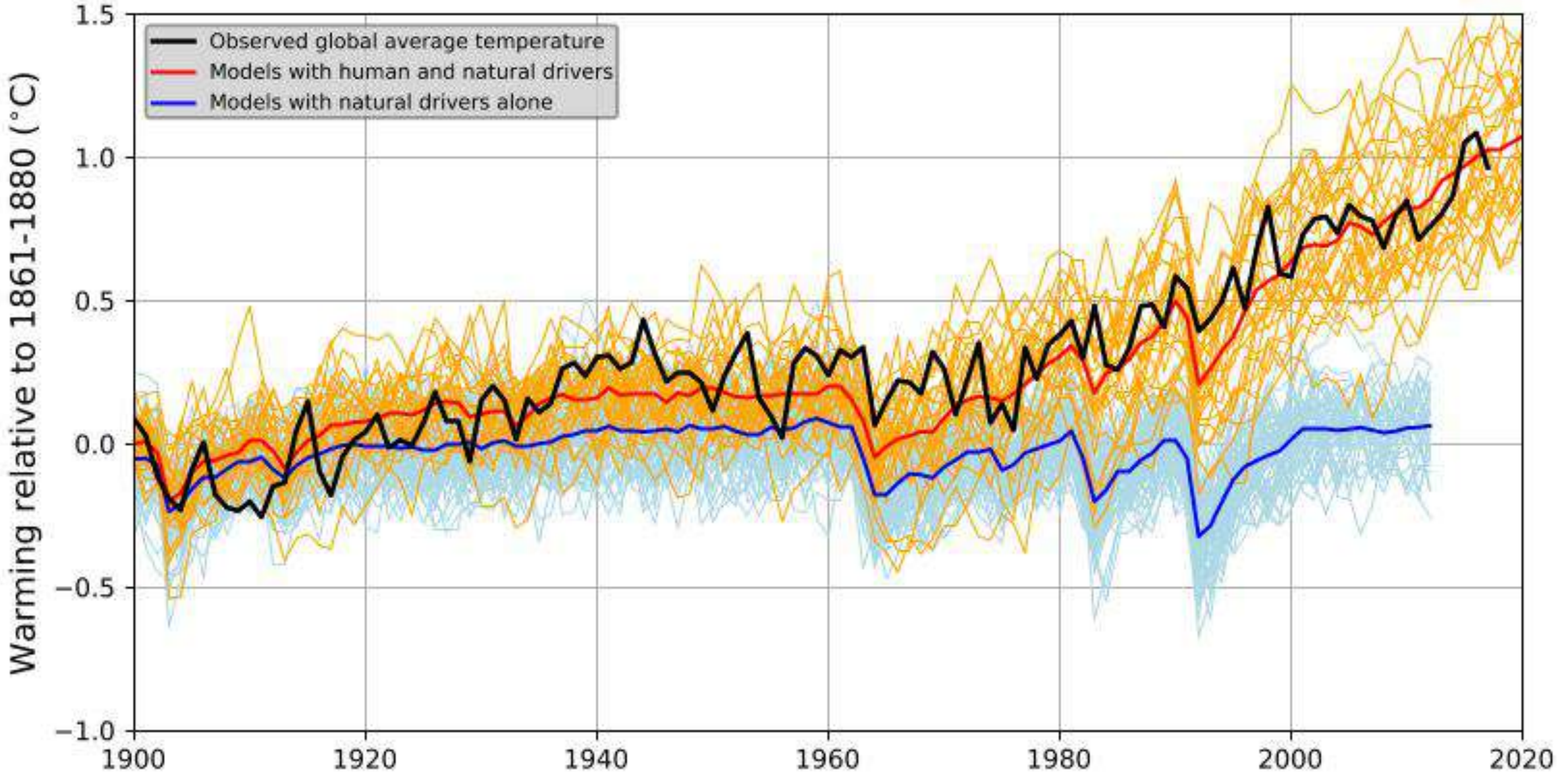


Ghiacciaio di Teleccio (Gran Paradiso)

Global Climate Models



Climate models reproduce observed warming only when human influences are included



Richardson et al, 2017