Target Atmospheric CO_2: Where Should Humanity Aim?

James Hansen[*,1,2], Makiko Sato[1,2], Pushker Kharecha[1,2], David Beerling[3], Robert Berner[4], Valerie Masson-Delmotte[5], Mark Pagani[4], Maureen Raymo[6], Dana L. Royer[7] and James C. Zachos[8]

[1]*NASA/Goddard Institute for Space Studies, New York, NY 10025, USA*

[2]*Columbia University Earth Institute, New York, NY 10027, USA*

[3]*Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, UK*

[4]*Department of Geology and Geophysics, Yale University, New Haven, CT 06520-8109, USA*

[5]*Lab. Des Sciences du Climat et l'Environnement/Institut Pierre Simon Laplace, CEA-CNRS-Universite de Versailles Saint-Quentin en Yvelines, CE Saclay, 91191, Gif-sur-Yvette, France*

[6]*Department of Earth Sciences, Boston University, Boston, MA 02215, USA*

[7]*Department of Earth and Environmental Sciences, Wesleyan University, Middletown, CT 06459-0139, USA*

[8]*Earth & Planetary Sciences Dept., University of California, Santa Cruz, Santa Cruz, CA 95064, USA*

Abstract: Paleoclimate data show that climate sensitivity is ~3°C for doubled CO_2, including only fast feedback processes. Equilibrium sensitivity, including slower surface albedo feedbacks, is ~6°C for doubled CO_2 for the range of climate states between glacial conditions and ice-free Antarctica. Decreasing CO_2 was the main cause of a cooling trend that began 50 million years ago, the planet being nearly ice-free until CO_2 fell to 450 ± 100 ppm; barring prompt policy changes, that critical level will be passed, in the opposite direction, within decades. If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm, but likely less than that. The largest uncertainty in the target arises from possible changes of non-CO_2 forcings. An initial 350 ppm CO_2 target may be achievable by phasing out coal use except where CO_2 is captured and adopting agricultural and forestry practices that sequester carbon. If the present overshoot of this target CO_2 is not brief, there is a possibility of seeding irreversible catastrophic effects.

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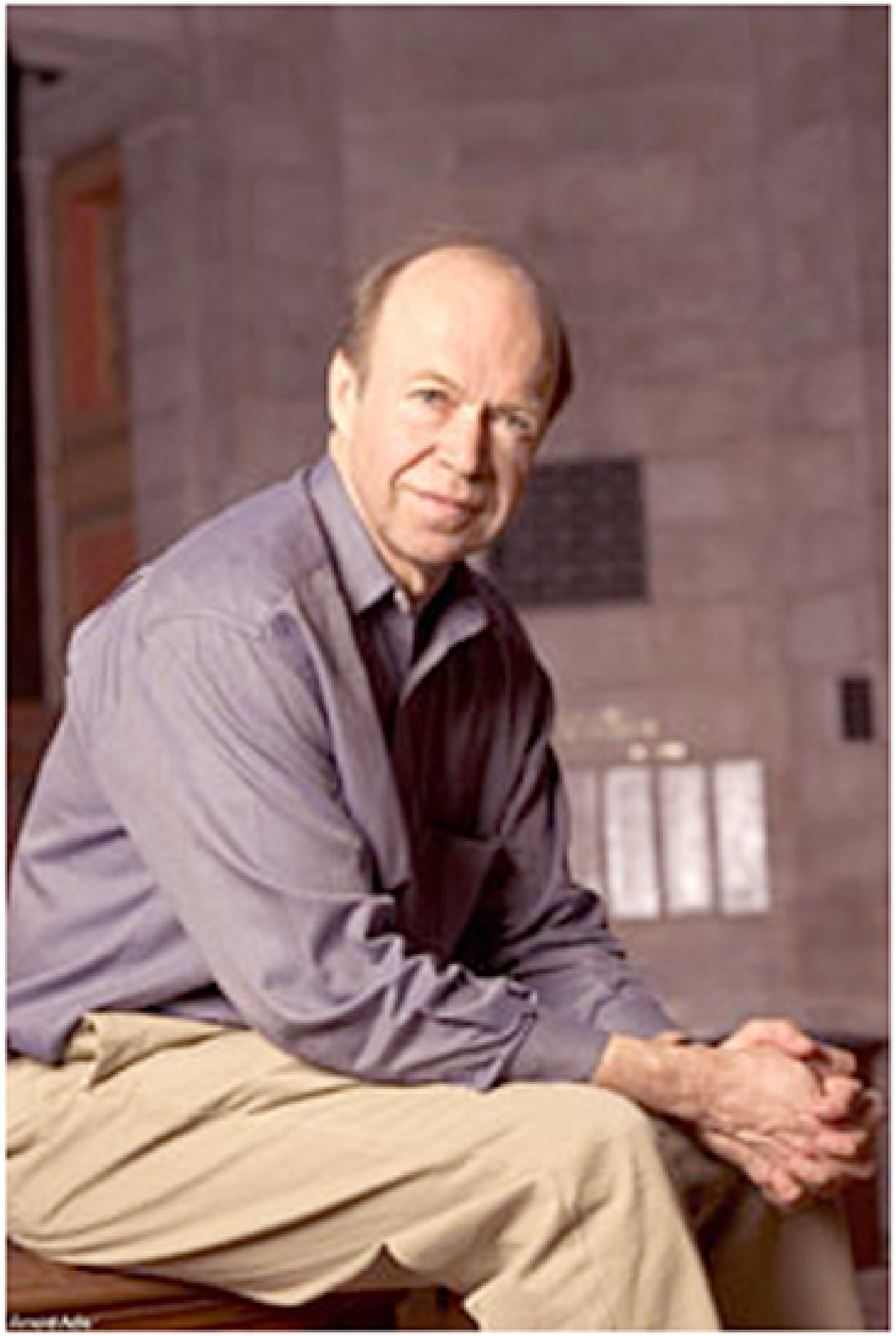
Dr. James E. Hansen

Affiliation: National Aeronautics and Space Administration

NASA Goddard Institute for Space Studies
2880 Broadway
New York, NY 10025 USA

E-mail: James.E.Hansen@nasa.gov
Phone: (212) 678-5500



Curriculum Vitae

- Download CV (PDF)

Education:

- B.A., Physics and Mathematics, 1963, University of Iowa
- M.S., Astronomy, 1965, University of Iowa
- Ph.D., Physics, 1967, University of Iowa

Publications

- Go to bibliography

http://www.giss.nasa.gov/staff/jhansen.html

Also, see the June 19, 2009 issue of *The New Yorker,* **pp 39 - 45.**

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"Target Atmospheric CO2: Where Should Humanity Aim?"
by James Hansen, et al

Richard McGehee
School of Mathematics
April 16, 2008

http://www.math.umn.edu/ > Seminars > Climate Change > References > Presentations

Outline

1.0 **Introduction** 1.0.4, 5: 385 ppm CO_2 is already too high

1.1 **Climate Sensitivity**

1.1.2 Charney [13] www.atmos.ucla.edu/~brianpm/download/charney_report.pdf

1.1.3 Feedbacks: Fast, Slow

1.1.4 Charney: Climate Models: $3 \pm 1.5°C$ increase fast-feedback due to CO_2 doubling

2.0 **Pleistocene Epoch**

2.0.1 Check fast-feedback (Charney) assessment LGM (last glacial maximum 20 ky BP) thru pre-industrial Holocene (about 1750): energy balance within $<< 1W/m^2$; ($1W/m^2$ imbalance over a few millennia: ice-free [Table S1 of 8])

2.0.2 Charney sensitivity $3 \pm 1.5°C \longleftrightarrow 4W/m^2 \longleftrightarrow CO_2$ doubling

2.0.3 Mention of "runaway greenhouse effect" [12].

2.1 **Verification** (fast-feedback) Describes how this paper's methods differ from [7]:
Hansen J, Sato M, Kharecha P, Russell G, Lea DW, Siddall M. Climate change and trace gases. Phil Trans Royal Soc A 2007; 365: 1925-54.

2.2 Slow feedbacks (a few millennia) Equilibrium sensitivity for slow feedbacks:

$$6° \text{ for } CO_2 \text{ doubling, } 1.5°C \text{ per } W/m^2.$$

2.2.8 Carbon-cycle models mentioned for long term influence of airborne GHGs.

2.3 **Time Scales**

2.3.2 Ocean: One-third in first few years, half in about 25 years, then full over a millennium.

2.3.3, 4: Ice sheet response takes millennia - except for now! 2.4 Warming "in the pipeline"

2.4.2, 3: $2°C$ warming is on the way, $.6°C$ (fast-feedback) and $1.4°C$ due to slow surface albedo feedback due to ice sheet disintegration and vegetation change.

3.0 **Cenozoic Era** (past 65.5 My)

This period splits, about 35 My BP, between "hot" and "cold," as shown in the dramatic Figure (3).
3.0.4 on: Figure (3) is discussed.

3.1 **Cenozoic Carbon Cycle**
3.1.3, 4: Figure (3) is used again in connection with India's move north toward Asia.
3.2 **Cenozoic Forcing and** CO_2
Technicalities. . . resemblance to Figure (3) again. . .

3.3 **Implication**
Again relying on Figure (3) – like information, our behavior now might turn us back toward an ice-free world, with sea level rises of "several meters per century."

4.0 **Anthropocene Era**

Recent industrial-era global climate forcings have produced the danger of raising global temperature to at least those of the Pliocene, 2 to 3 My BP; this is part of warming "in the pipeline."

4.1 **Tipping Points**
4.1.1 Dangers
4.1.2 (1) *tipping level,* global forcing leading toward specific results; (2) *point of no return,* a climate state, once reached, that *must* lead to the specific consequence.
4.1.3 (2)-results are difficult to define.
4.1.4 (1)-results are easier, based on paleoclimate information. Such forcings are those that humanity must aim to stay beneath.

4.2 **Target** CO_2
A dire subsection. Here are some brief truncated quotes.

"... total GHG climate forcing change is now determined mainly by CO_2...."

"Our estimated history of CO_2 through the Cenozoic Era provides a sobering perspective for assessing an appropriate target for future CO_2 levels. A CO_2 amount of order 450 ppm or larger, if long maintained, would push Earth toward the ice-free state."

"The climate system, because of its inertia, has not yet fully responded to the recent increase of human-made climate forcings...."

"...increased aridity in southern United States ..., the Mediterranean region, Australia and parts of Africa...support the conclusion that 385 ppm CO_2 is already deleterious."

"Equilibrium sea level rise for today's 385 ppm CO_2 is at least several meters"

"Stabilization of Arctic sea ice cover requires, to first approximation, restoration of planetary energy balance."

"A further imbalance reduction, and thus CO_2 300-325 ppm, may be needed to restore sea ice to its area of 25 years ago."

"Coral reefs are suffering from multiple stresses, with ocean acidification and ocean warming principal among them.... Given additional warming in-the-pipeline, 385 ppm CO_2 is already deleterious. A 300-350 ppm CO_2 target would significantly relieve both of these stresses"

Earth's energy imbalance: Confirmation and implications - ossfoundation.com [PDF]

4.3 CO_2 Scenarios

Again, a quote:

"A large fraction of fossil fuel CO_2 emissions stays in the air a long time, one-quarter remaining airborne for several centuries [11, 78, 79]. Thus moderate delay of fossil fuel use will not appreciably reduce long-term human-made climate change. Preservation of a climate resembling that to which humanity is accustomed, the climate of the Holocene, requires that most remaining fossil fuel carbon is never emitted to the atmosphere.

Coal is the largest reservoir of conventional fossil fuels (Fig. **S**12), exceeding combined reserves of oil and gas [2, 79]. The only realistic way to sharply curtail CO_2 emissions is to phase out coal use except where CO_2 is captured and sequestered."

They go on to say that these levels might have to be adjusted downward.

4.4 Policy Relevance

The authors suggest *how* to reduce CO_2 density. Their suggestions range from the development of technology to reduce CO_2 in the air and carbon sequestration using *biochar* as well as improved agricultural and forestry practices and CO_2 capture at power plants.

4.4.(last ¶) addresses the need for prices on carbon emission and payment for sequestration, and comes to a pessimistic conclusion that "business-as-usual" will result in a dangerous overshoot of the 350 ppm level.

4.5 Caveats: **Climate Variability, Climate Models, and Uncertainties**

A discussion about the many difficulties in making assessments and predictions that overcomes excessively large uncertainties. But one point recurs: humanity disrupting Earth's climate balance cannot be continued with impunity!

5 Summary

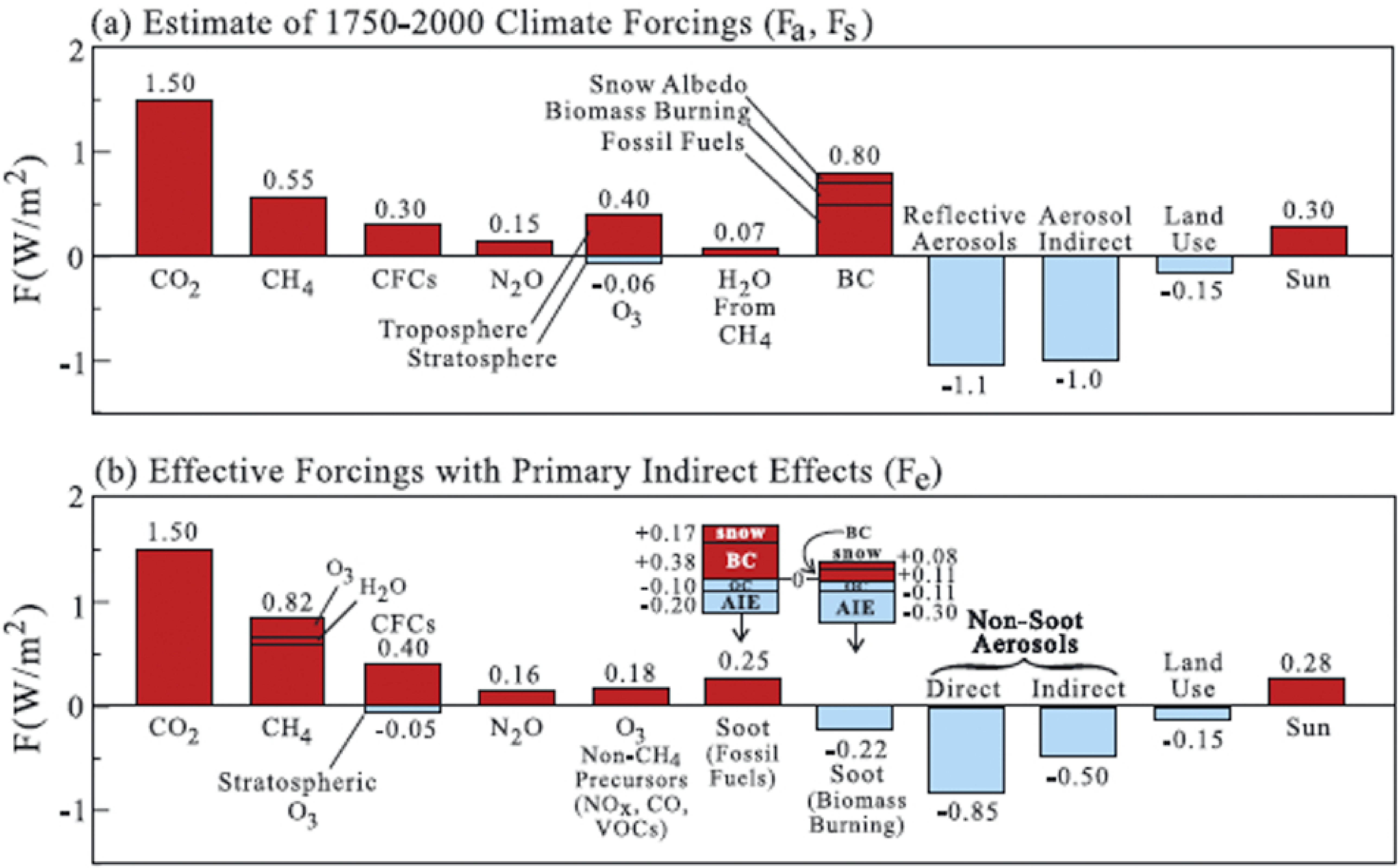


Figure 28. (a) A specific estimate of climate forcings for 1750–2000. (b) Same as Figure 28a, but with the effective forcing partially sorted by sources.

Hansen, J., et al. (2005), Efficacy of climate forcings, J. Geophys. Res., 110, D18104, doi:10.1029/2005JD005776

Humanity today, collectively, must face the uncomfortable fact that industrial civilization itself has become the principal driver of global climate.

Figures (2) and (7) might support this statement.

The first we have seen before -- as the eleventh slide in Richard McGehee's April 16th presentation last year.

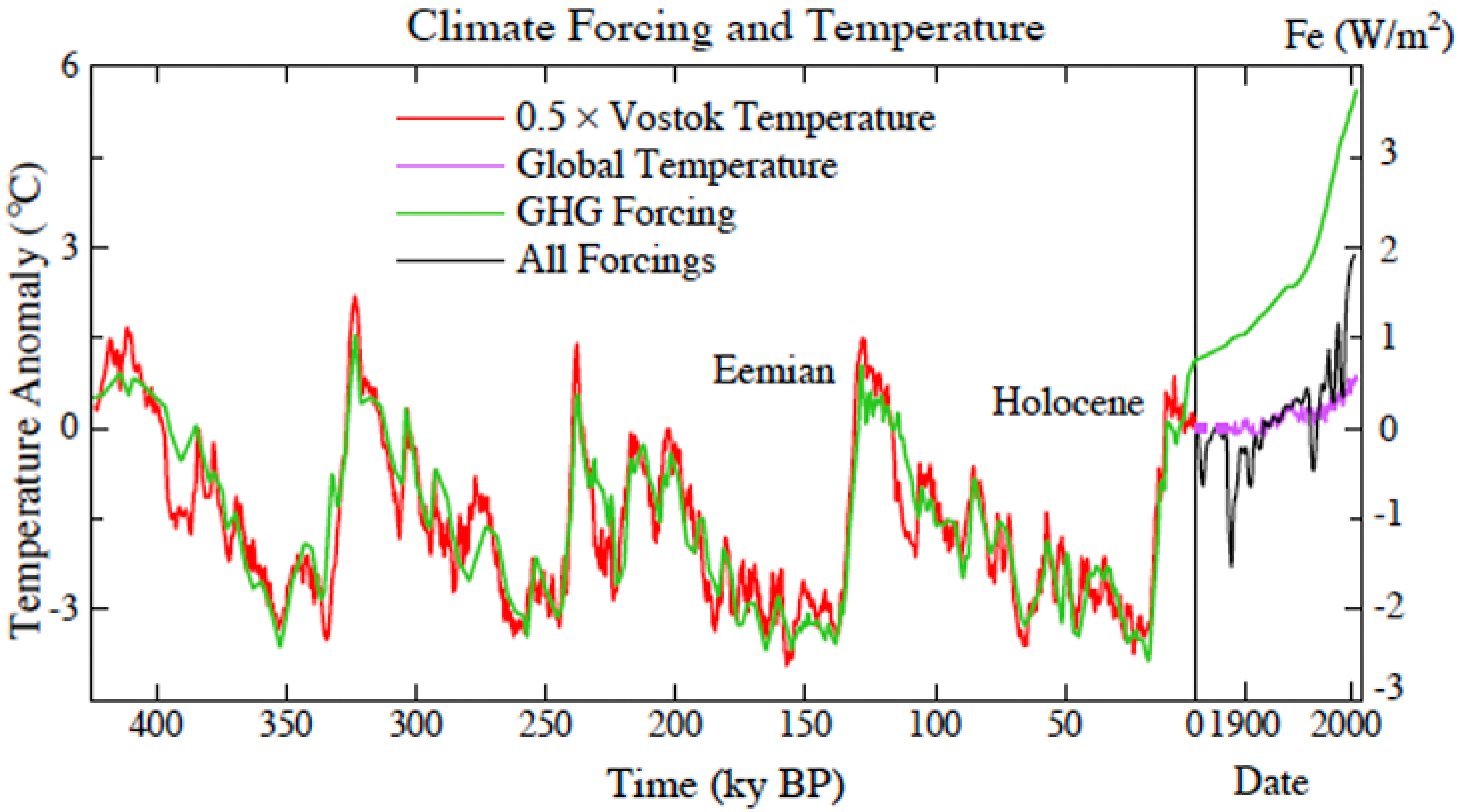


Fig. (2). Global temperature (left scale) and GHG forcing (right scale) due to CO_2, CH_4 and N_2O from the Vostok ice core [17, 18]. Time scale is expanded for the industrial era. Ratio of temperature and forcing scales is 1.5°C per W/m^2, i.e., the temperature scale gives the expected equilibrium response to GHG change including (slow feedback) surface albedo change. Modern forcings include human-made aerosols, volcanic aerosols and solar irradiance [5]. GHG forcing zero point is the mean for 10-8 ky BP (Fig. S6). Zero point of modern temperature and net climate forcing was set at 1850 [5], but this is also the zero point for 10-8 ky BP, as shown by the absence of a trend in Fig. (S6) and by the discussion of that figure.

Humanity today, collectively, must face the uncomfortable fact that industrial civilization itself has become the principal driver of global climate.

Figures (2) and (7) might support this statement.

The second concentrates on the period from 1950 to about 2008.

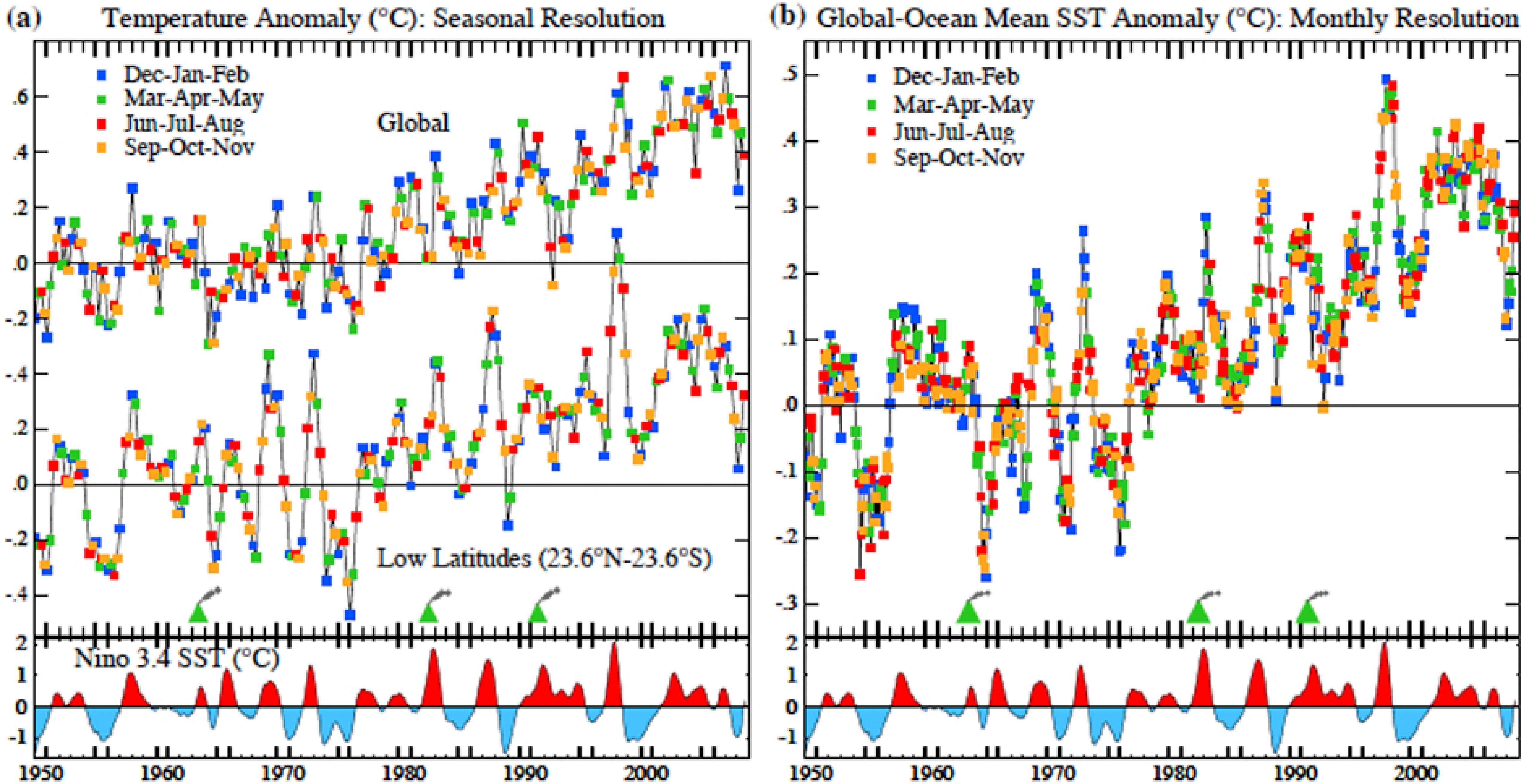


Fig. (7). (**a**) Seasonal-mean global and low-latitude surface temperature anomalies relative to 1951-1980, an update of [92], (**b**) global-ocean-mean sea surface temperature anomaly at monthly resolution. The Nino 3.4 Index, the temperature anomaly (12-month running mean) in a small part of the tropical Pacific Ocean [93], is a measure of ENSO, a basin-wide sloshing of the tropical Pacific Ocean [94]. Green triangles show major volcanic eruptions.

If we stay our present course, using fossil fuels to feed a growing appetite for energy-intensive life styles, we will soon leave the climate of the Holocene, the world of prior human history.

The next two slides: Figure S6, from the Supplementary Material, covers 20,000 years. The next one was prepared by Robert A. Rohde for "Global Warming Art."

The slide following those two is Figure (6.10) from:

IPCC Fourth Assessment Report (AR4)

Climate Change 2007: The Physical Science Basis
Chapter 6 Palaeoclimate

Jansen, E., J. Overpeck, K.R. Briffa, J.-C. Duplessy, F. Joos, V. Masson-Delmotte, D. Olago, B. Otto-Bliesner, W.R. Peltier, S. Rahmstorf, R. Ramesh, D. Raynaud, D. Rind, O. Solomina, R. Villalba and D. Zhang, 2007: Palaeoclimate. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

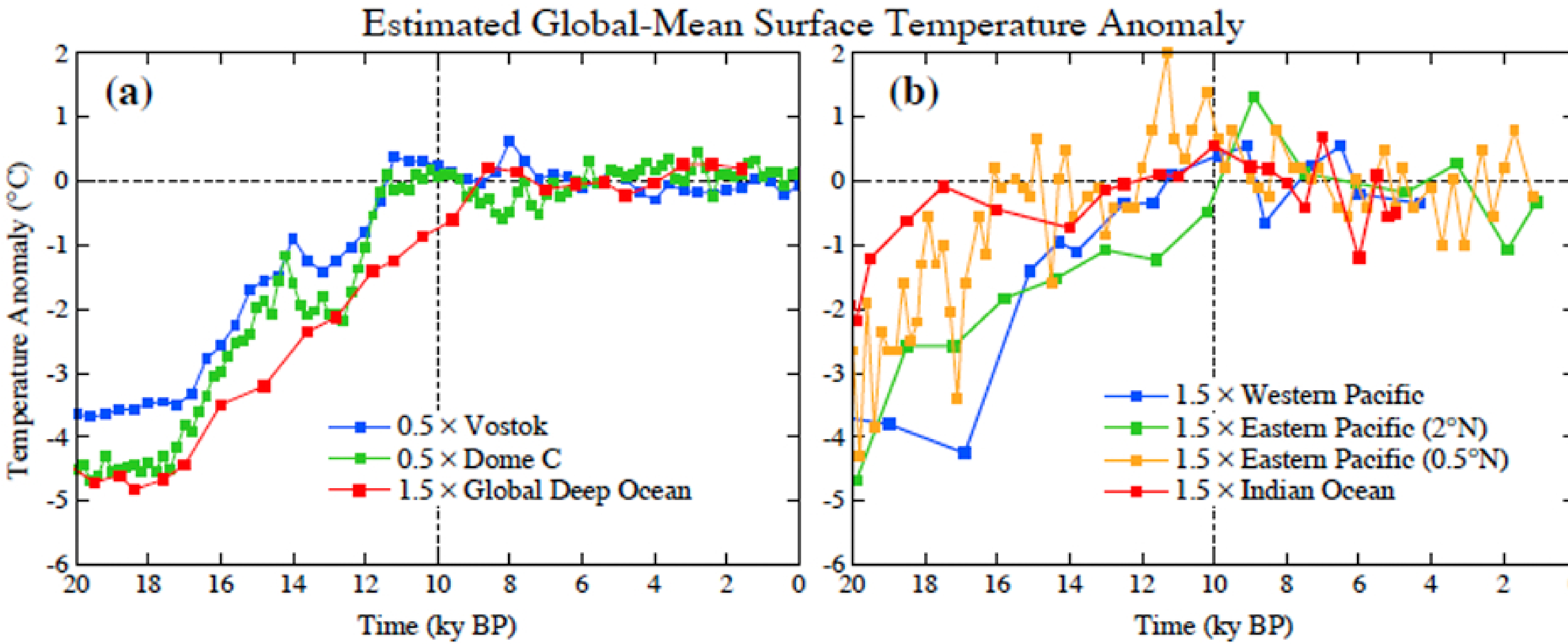
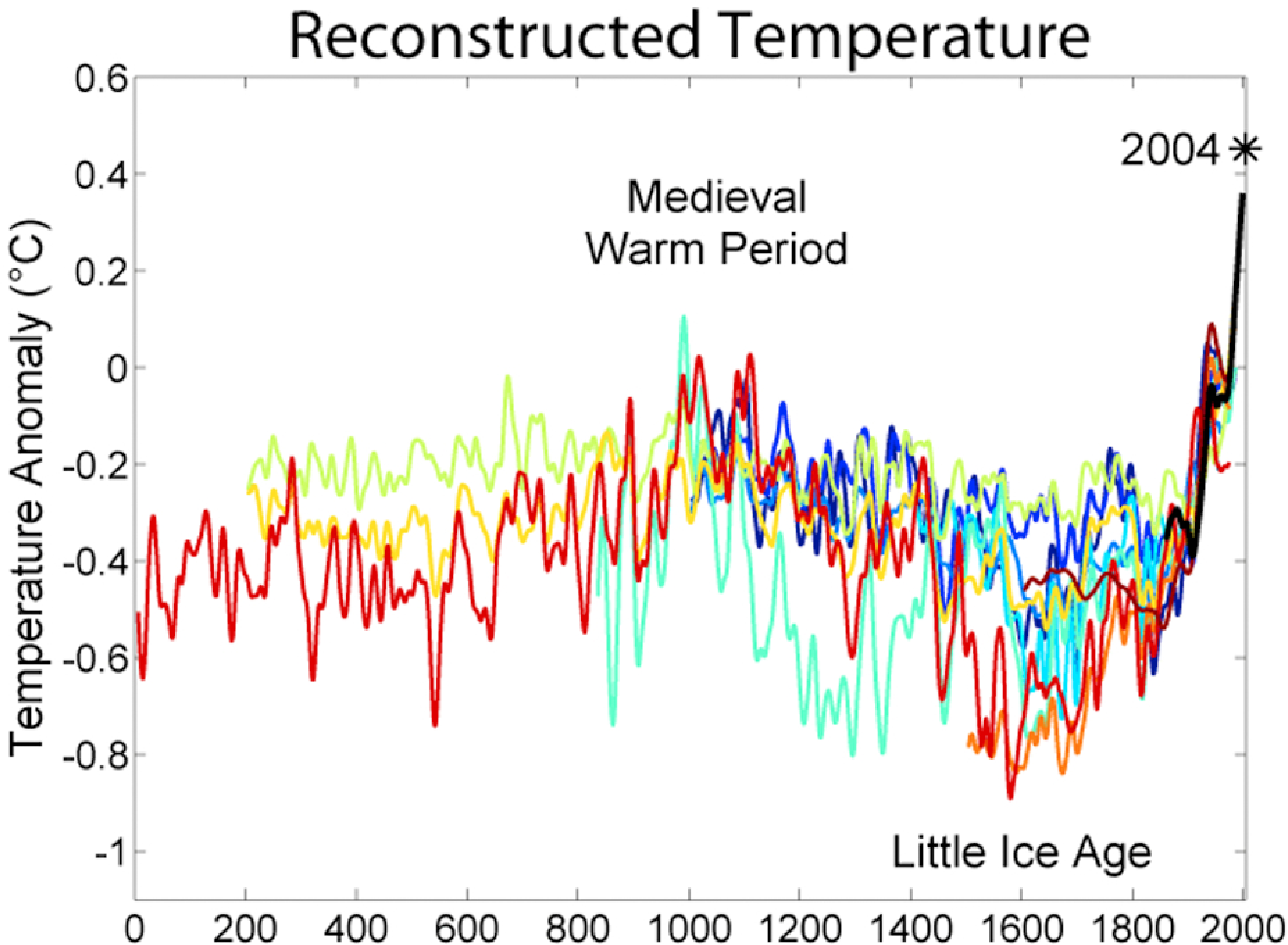
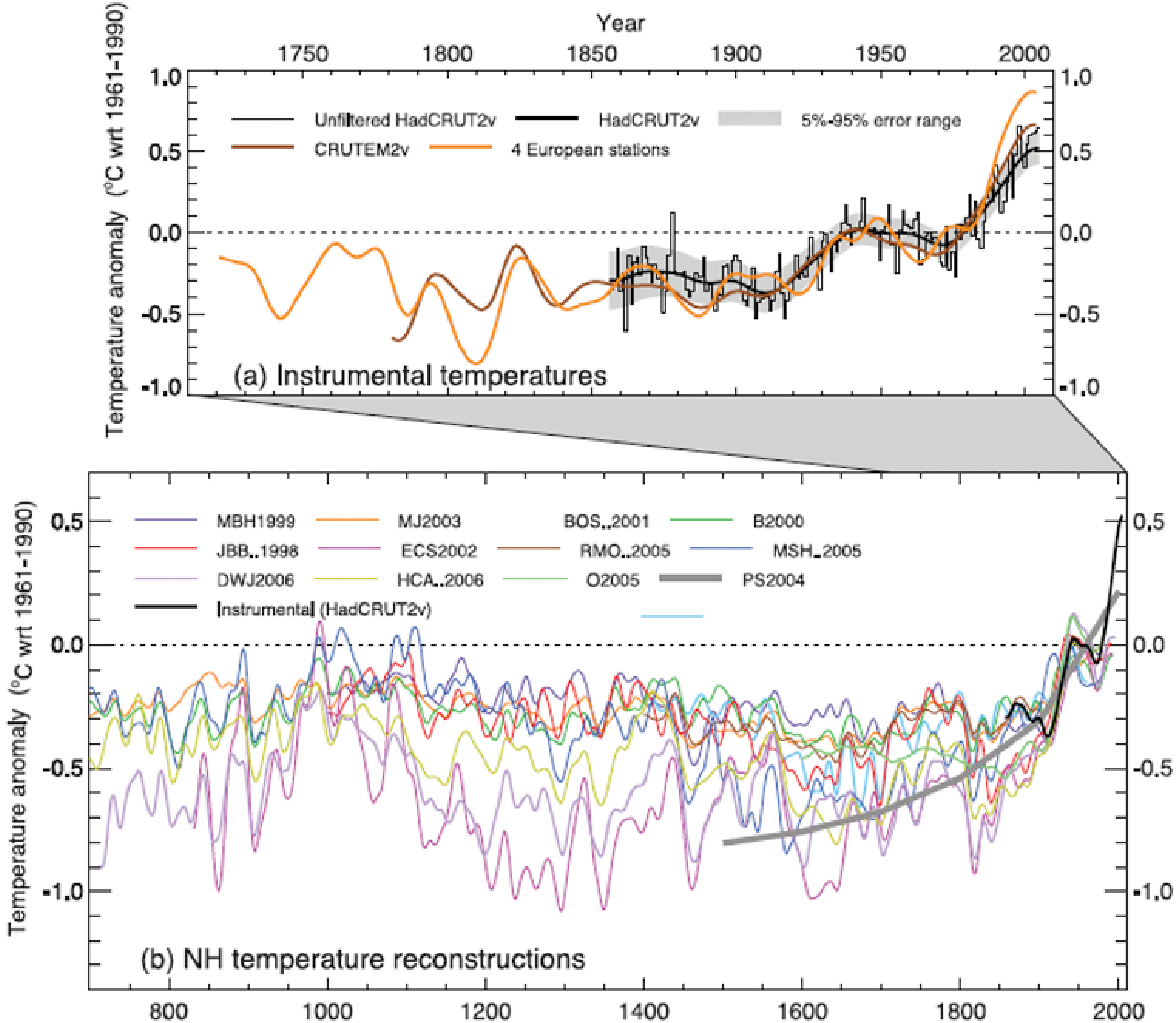


Fig. (S6). Estimates of global temperature change inferred from Antarctic ice cores [18, S8] and ocean sediment cores [S9-S13], as in Fig. (S5) but for a period allowing Holocene temperature to be apparent.

http://commons.wikimedia.org/wiki/File:2000_Year_Temperature_Comparison.png



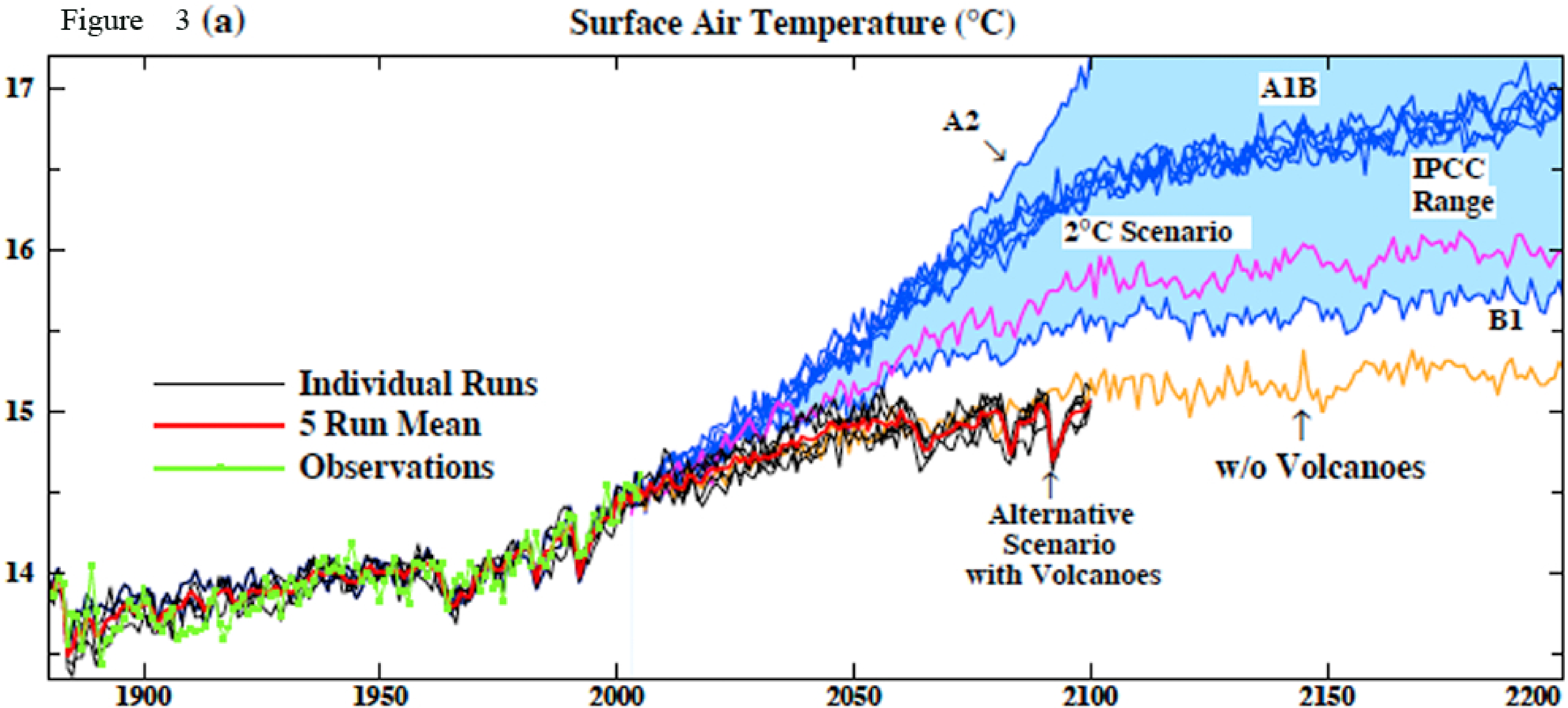

Year
1750
1800
1850
1900
1950
2000
Unfiltered HadCRUT2v
HadCRUT2v
5%-95% error range
CRUTEM2v
4 European stations
(a) Instrumental temperatures
Temperature anomaly (°C wrt 1961-1990)
1.0
0.5
0.0
-0.5
-1.0
MBH1999
MJ2003
BOS..2001
B2000
JBB..1998
ECS2002
RMO..2005
MSH..2005
DWJ2006
HCA..2006
O2005
PS2004
Instrumental (HadCRUT2v)
(b) NH temperature reconstructions
800
1000
1200
1400
1600
1800
2000

If we stay our present course, using fossil fuels to feed a growing appetite for energy-intensive life styles, we will soon leave the climate of the Holocene, the world of prior human history.

Finally, we can look at projections for the next 200 years, taken from

"Dangerous human-made interference with climate: a GISS modelE study,"
J Hansen et al, Atmos. Chem. Phys., 7, 2287–2312, 2007

Figure 3 **(a)**



Forcing agent	Run name	Fi 2000–2100	Fa	ΔTs (2000 to Year Below) 2050	2100	2200	2300
A2	E3IP_A2	6.67	6.23	1.06	2.71	3.33	3.70
A1B	E3IP_A1B	4.72	4.36	1.04	1.99	2.51	2.75
B1	E3IP_B1	2.61	2.38	0.73	1.20	1.36	1.54
2°C Scenario w/o Volcanoes	E3_2Cx	3.08	2.85	0.81	1.46	1.66	–

part of Table 1