The Evolving Role of Geoscientists in Climate Change Science*

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Abstract

In the on-going debate concerning natural versus anthropogenic drivers of modern climate change, a long-term geologic perspective is greatly needed. As geologists, we study and learn from the deep past, often in hundreds of thousands to hundreds of millions of years. We study the current geologic processes and use the principle of uniformity to recognize that the same processes and laws in operation today were also valid and operating in the past. One of the first principles we learned as undergraduates was "The present is the key to the past". In climate science, the geologist's role should be to use the corollary of this scientific principle to reverse the typical usage and apply the knowledge of the Earth's climate history to better predict what may happen in the future: "The past is the key to the future".

Much of the climate science used to bolster the notion that anthropogenic greenhouse gases are the primary driver of the current warming trend use only the relatively short period of instrumentation-based data. Direct measurements of carbon dioxide only began in 1958 at the Mauna Loa Observatory and thermometer-based temperature data extend back to the mid-19th century. The historical length of this data is just a blink of the eye to a geologist and provides a much skewed perspective on the relationship between CO_2 and temperature. A long-term geologic view is required to properly analyze the planet's climate history in order to better predict what may occur in the future.

A review of long-term climate history clearly shows that both temperature and CO_2 have risen and fallen dramatically and regularly for the last 600 million years and that changes over the last 100 or so years are neither unusual nor unprecedented. All of those past climate changes were 100% naturally driven and the processes driving the past changes did not suddenly end at the beginning of the Industrial Revolution. In today's politically charged atmosphere surrounding the climate-change debate, a geologic fact-based perspective is sorely needed.

The Evolving Role of Geoscientists in Climate Change Science

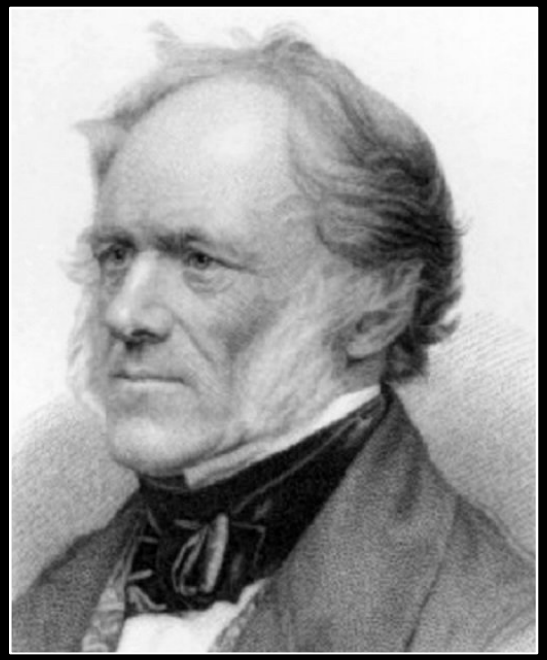
Gregory Wrightstone

American Association of Petroleum Geologists
Eastern Section Meeting
9/26/2017

The present is the key to the past

Principle of Uniformitarianism

James Hutton – The father of modern geology
Theory of the Earth (1785)



Sir Charles Lyell – Popularized the principle in
Principles of Geology (1830-1833)

The past is the key to the future

Geologic analysis, methods & thought processes should play a major role in climate science:

- Long-term viewpoint to provide context to today's changing climate
- Compare ancient climate changes to modern
- Compare ancient extremes (high CO2, high/low temperatures, etc.) to today

Current climate debate

No disagreement:

- CO2 has increased about 120 ppm since 1850
- Nearly all of the CO_2 increase is man-made
- Temperature has risen ~0.85°C **(1.5°F) since 1850**

Serious disagreement:

- Increase in temperature is primarily due to man-made increases in CO_2 (plus other greenhouse gases)

or

- Increase in temperature is driven primarily by natural forces with a small influence from man-made causes

Current climate science and reporting:

Focus on “recent” data and trends (decades to hundreds of years)

Little to no reporting of this “recent” climate data in a long-term geologic context.

Analyzing data: Context is everything

Direct measurements of climate data are only very recent

Carbon Dioxide

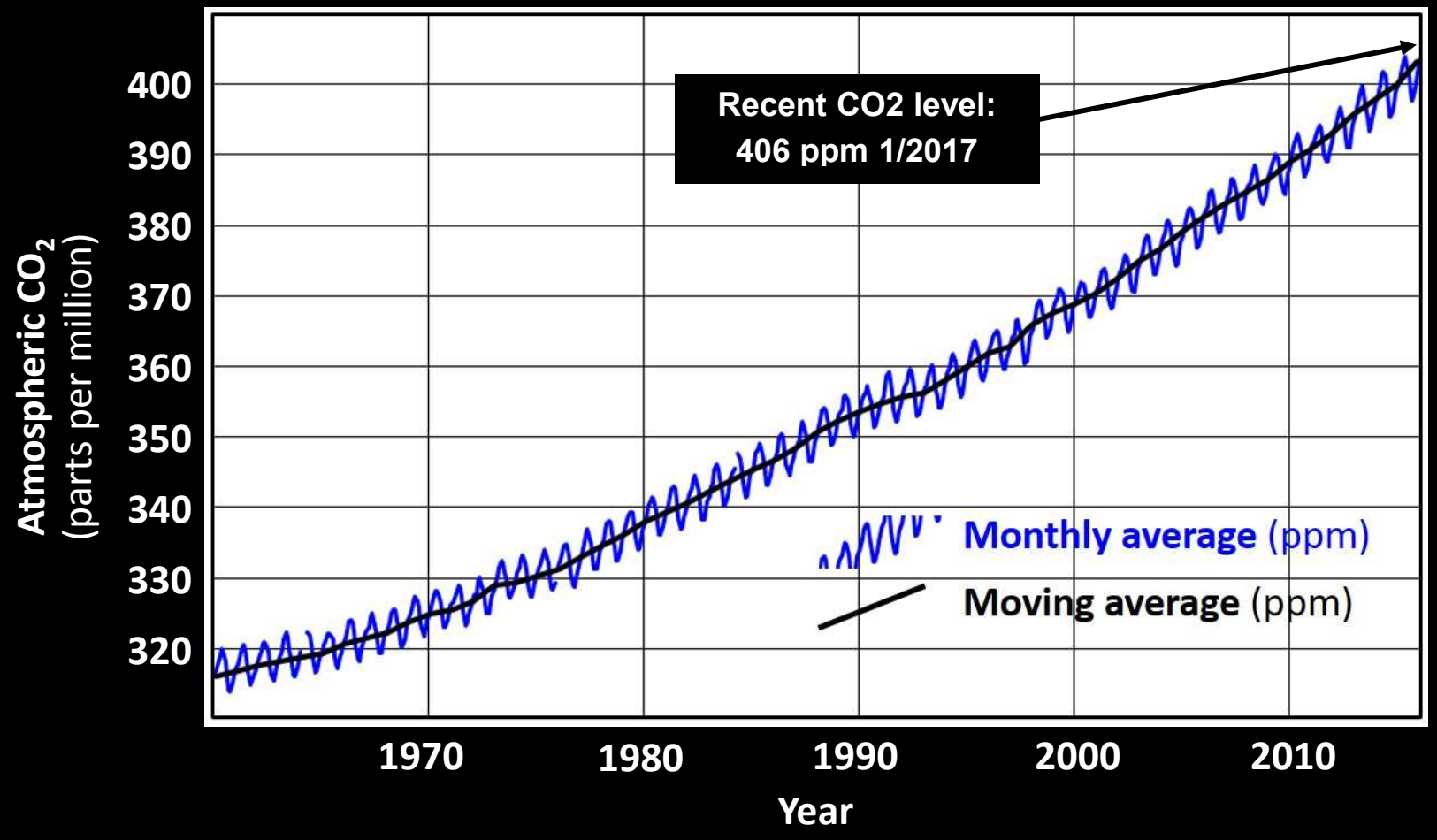
Method	First Used
Atmospheric (Mauna Loa)	1958

Temperature

Method	First Used
Land and ocean surface thermometers	1850 (1659)
Weather balloons	Mid-1950s
Satellites	1979

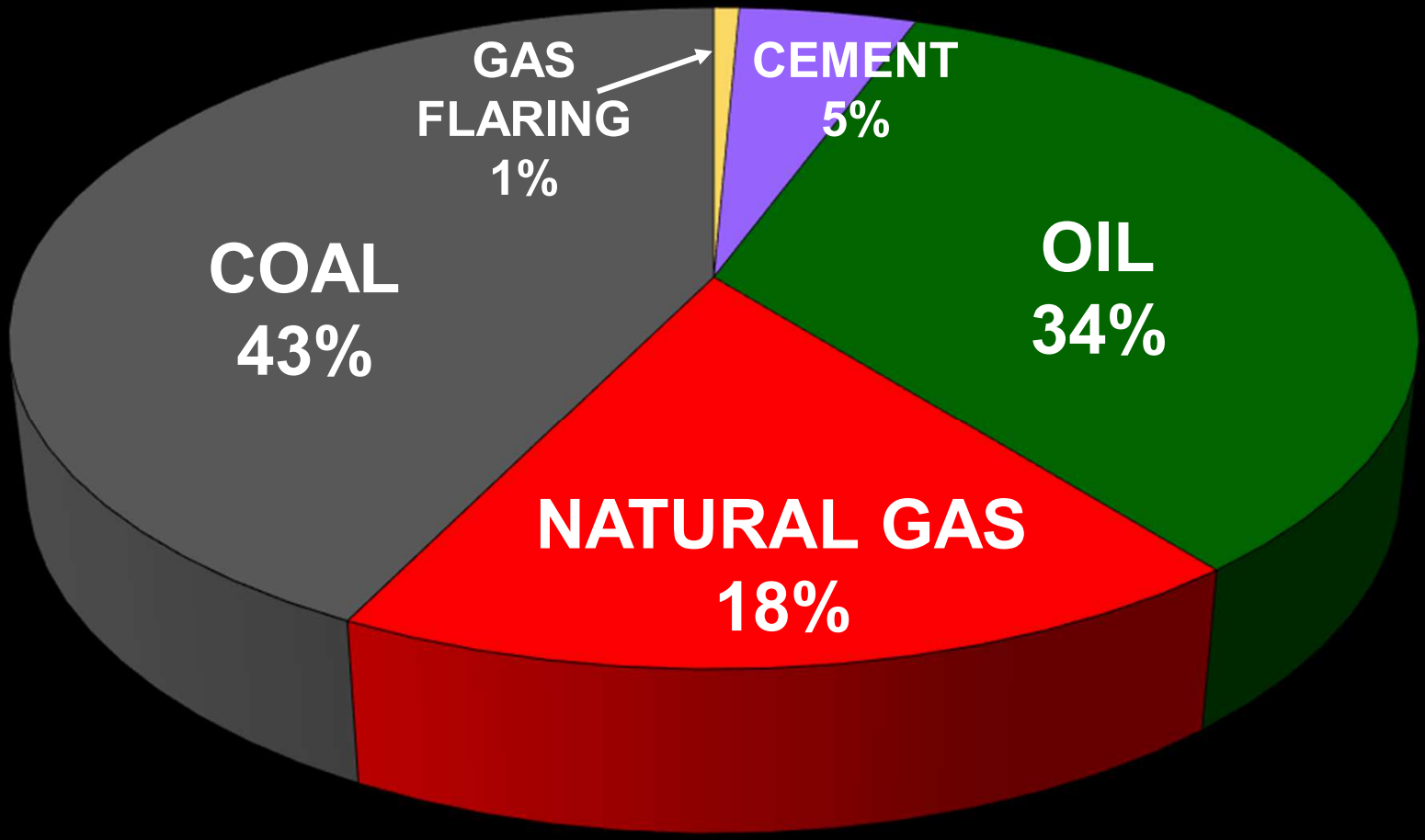
Carbon Dioxide

Recent CO_2 concentration @ Mauna Loa Observatory
1958 to 2016



Carbon Dioxide

Human generated sources of CO_2 - 2011

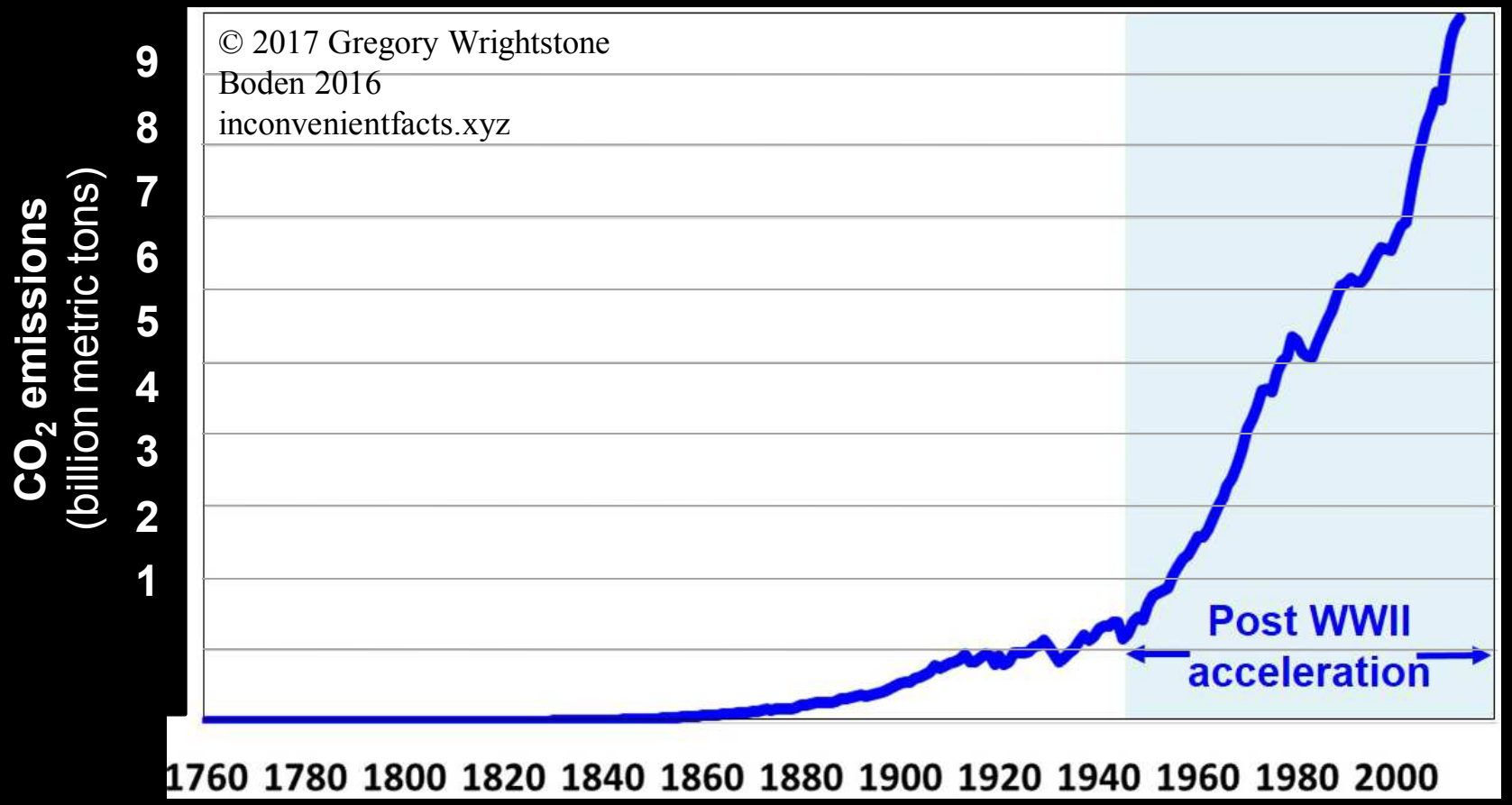


Le Quéré C, Andres RJ, Boden T, Conway T, Houghton RA, House JI, Marland G, Peters GP, van der Werf G, Ahlström A, Andrew RM, Bopp L, Canadell JG, Ciais P, Doney SC, Enright C, Friedlingstein P, Huntingford C, Jain AK, Jourdain C (2012) The global carbon budget 1959–2011, Earth System Science Data Discussions, 5(2), pp. 1107-1157. Copernicus 10.5194/essdd-5-1107-2012

Carbon Dioxide

CO_2 emissions 1759 – 2016

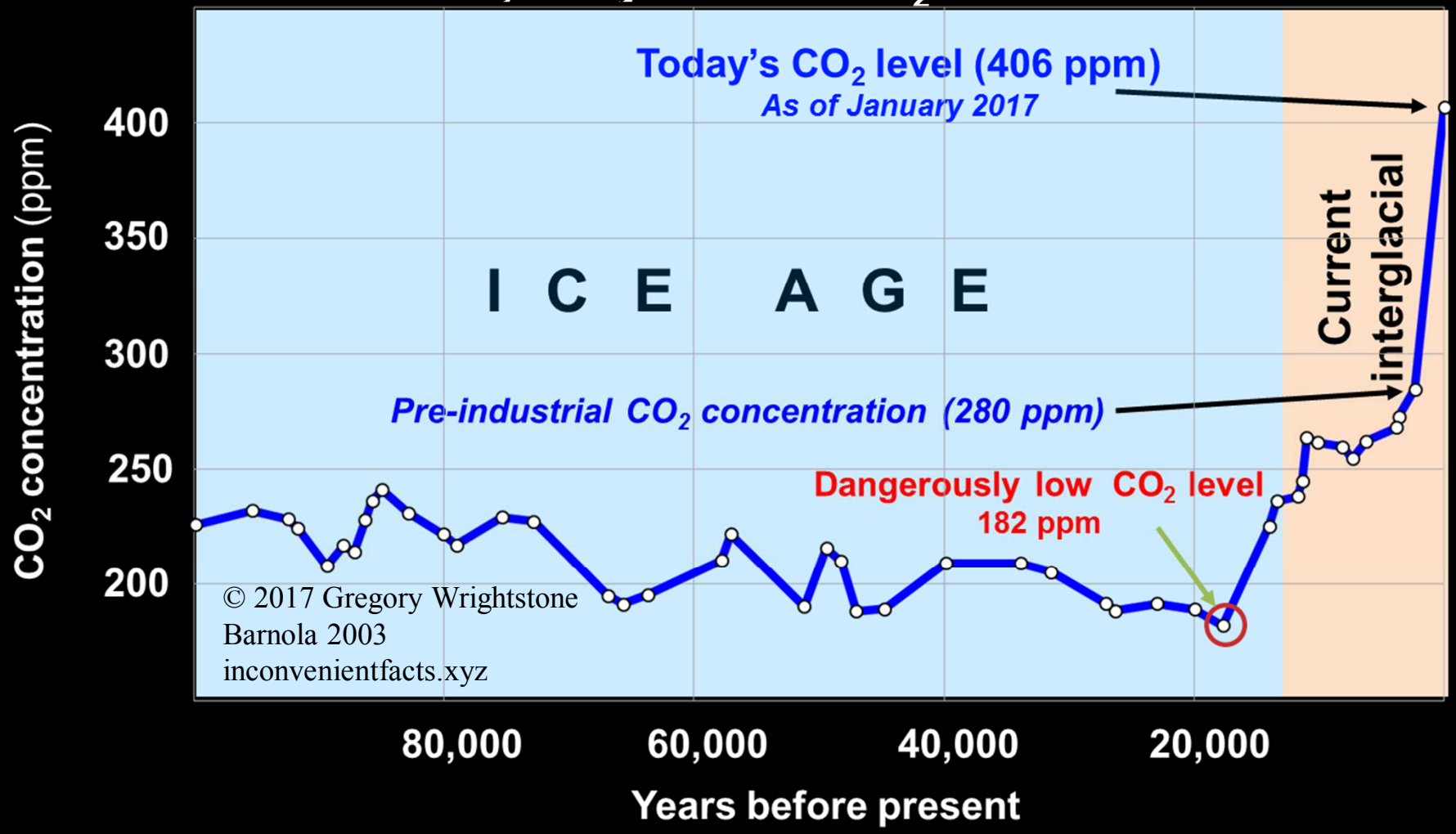
Fossil-Fuel Burning Cement Manufacture and Gas Flaring 1751 - 2013



Boden TA, Marland G, Andres RJ (2016) Global CO2 emissions from Fossil-Fuel Burning Cement Manufacture and Gas Flaring 1751 - 2013. CDIAC, Oak Ridge National Laboratory, U.S. Dept of Energy, Oak Ridge, TN, USA,

Carbon Dioxide

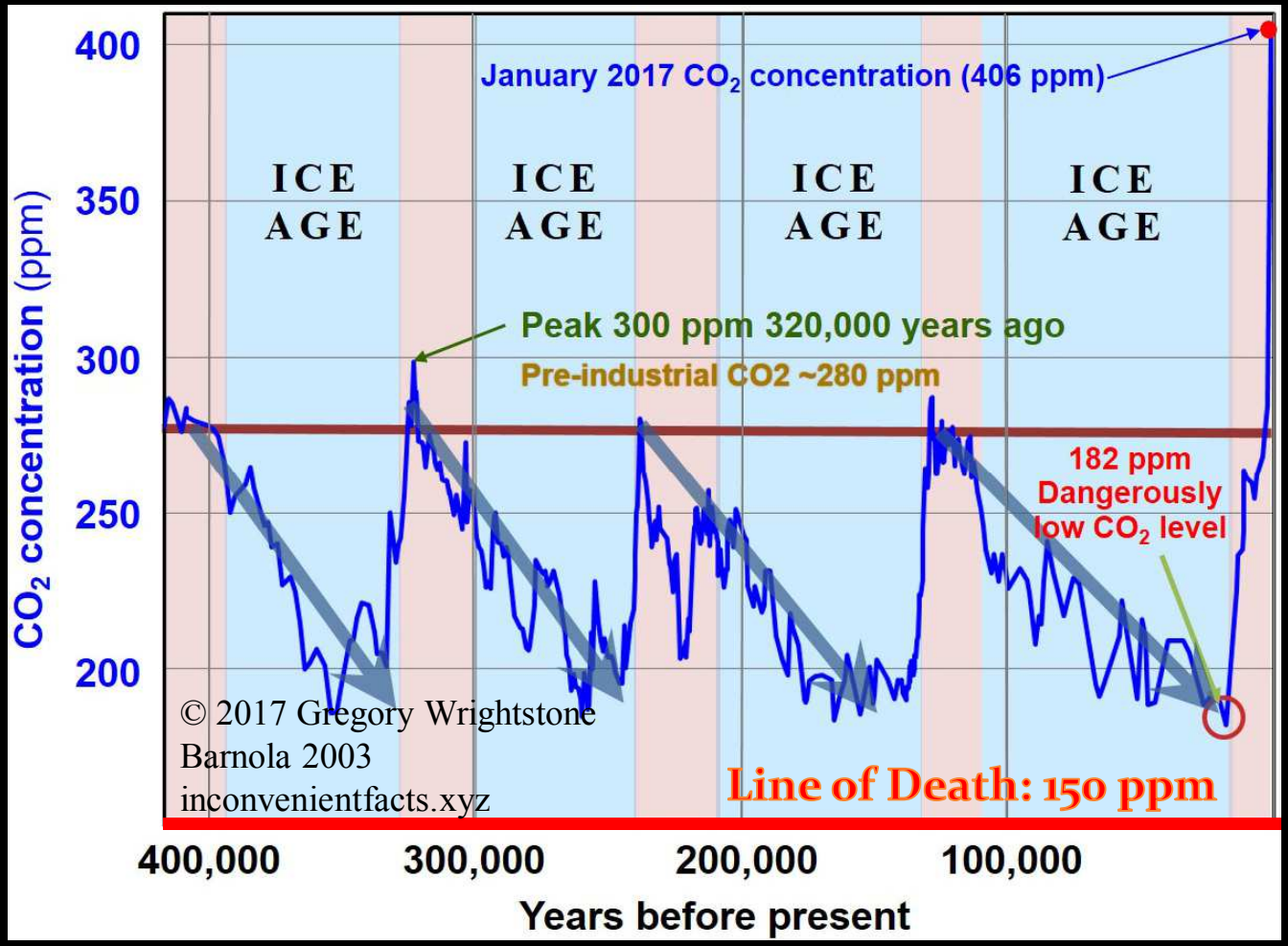
100,000 years of CO_2 data



Barnola JM, Raynaud D, Lorius C et al (2003) Historical CO2 record from the Vostok ice core. In Trends: A Compendium of Data on Global Change. CDIAC, Oak Ridge National Laboratory, U.S. Dept of Energy, Oak Ridge, TN, USA, http://cdiac.ornl.gov/ftp/trends/co2/vostok.icecore.co2

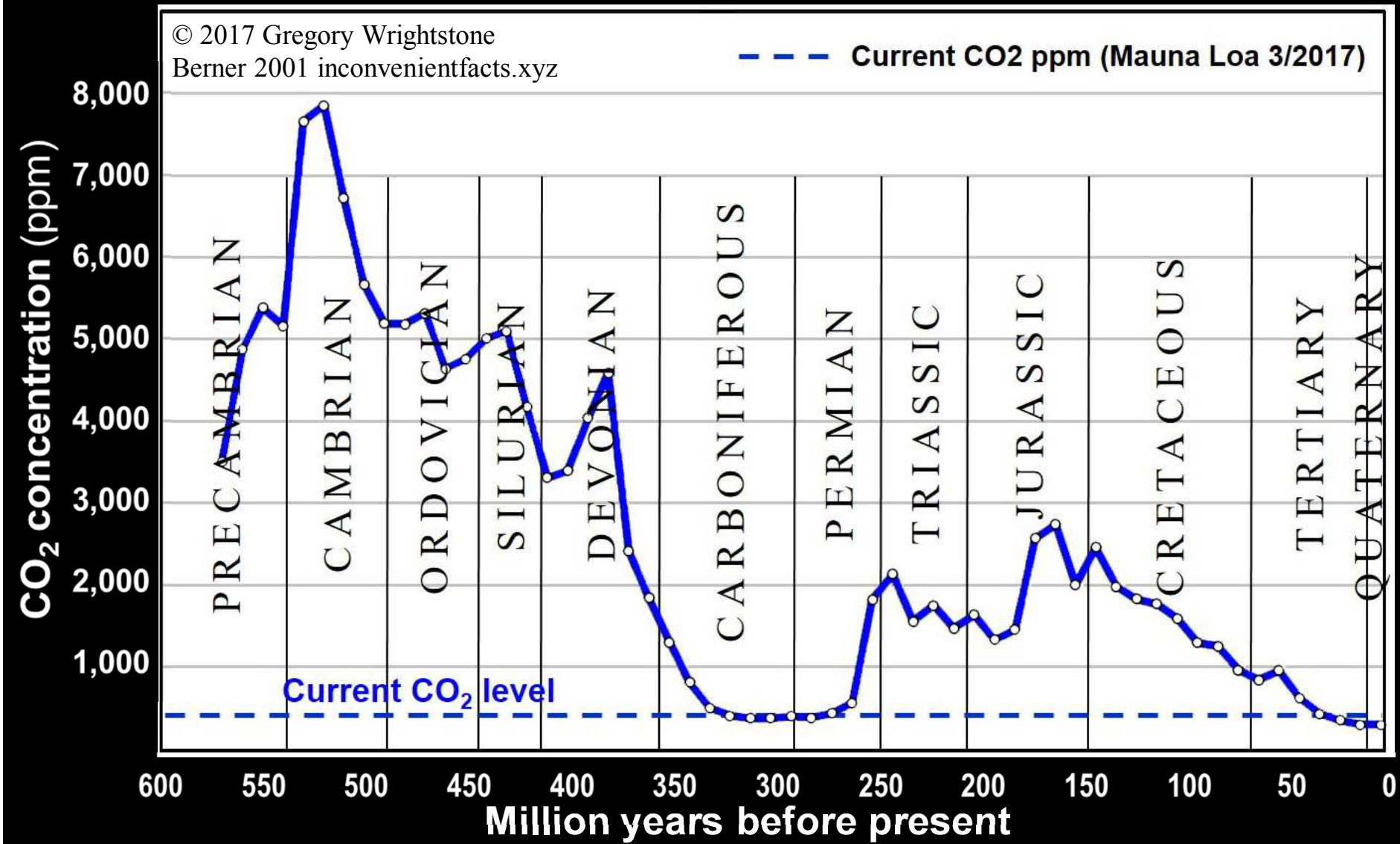
Carbon Dioxide

CO2 – 400,000 years of near extinction events - Vostok ice core Antarctica



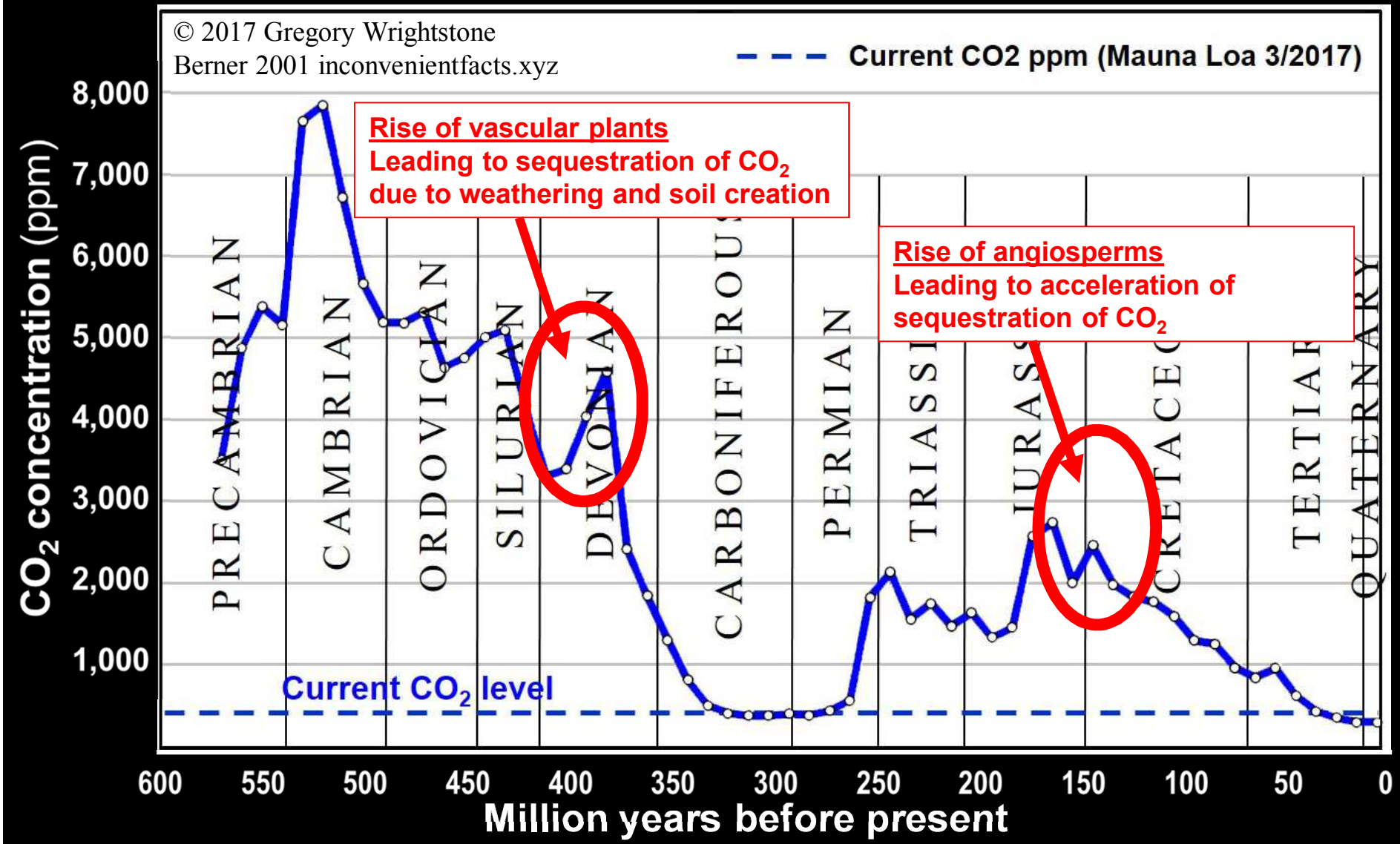
Barnola JM, Raynaud D, Lorius C et al (2003) Historical CO2 record from the Vostok ice core. In Trends: A Compendium of Data on Global Change. CDIAC, Oak Ridge National Laboratory, U.S. Dept of Energy, Oak Ridge, TN, USA, http://cdiac.ornl.gov/ftp/trends/co2/vostok.icecore.co2

CO_2 – 600 million years



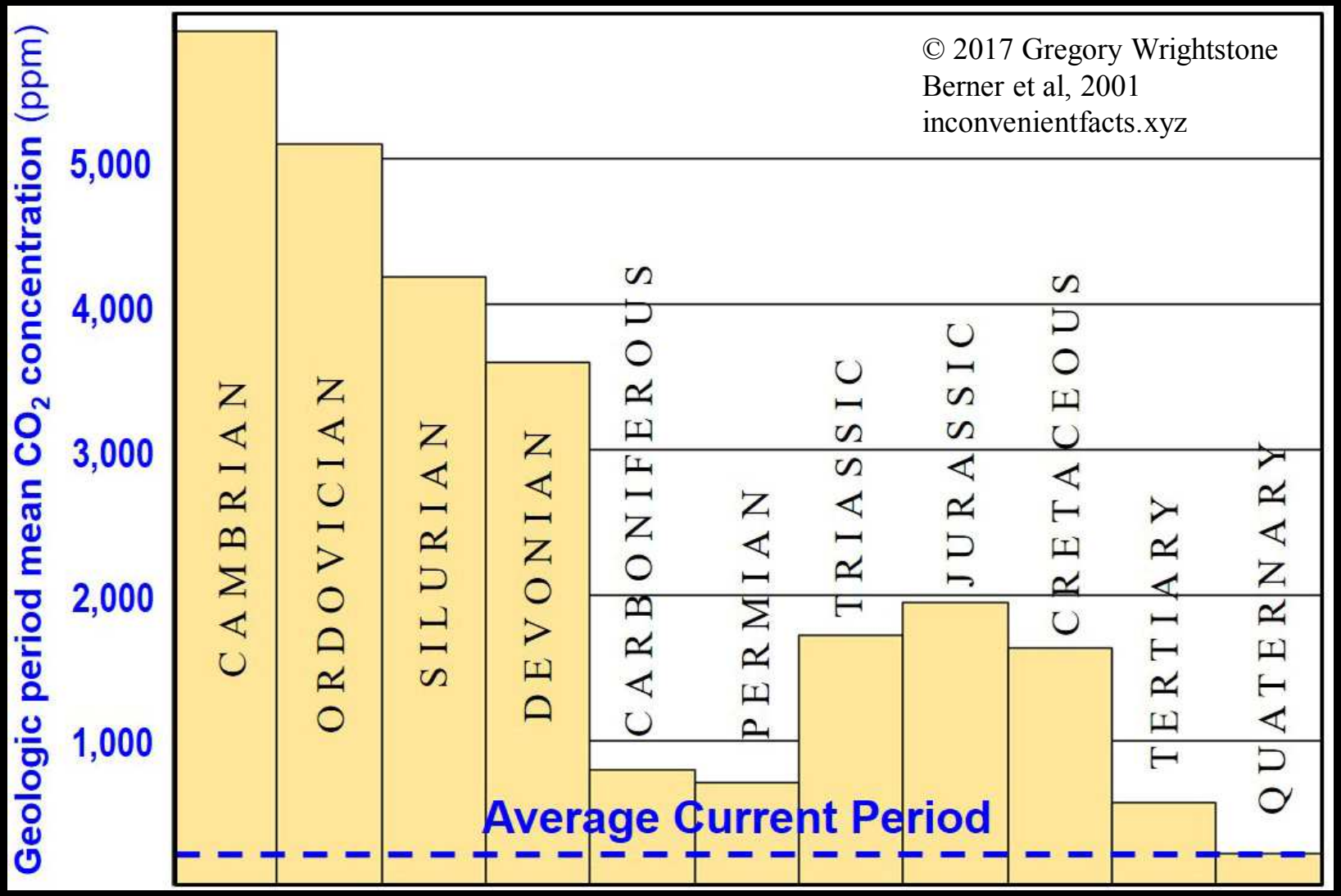
Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

CO_2 – 600 million years



Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

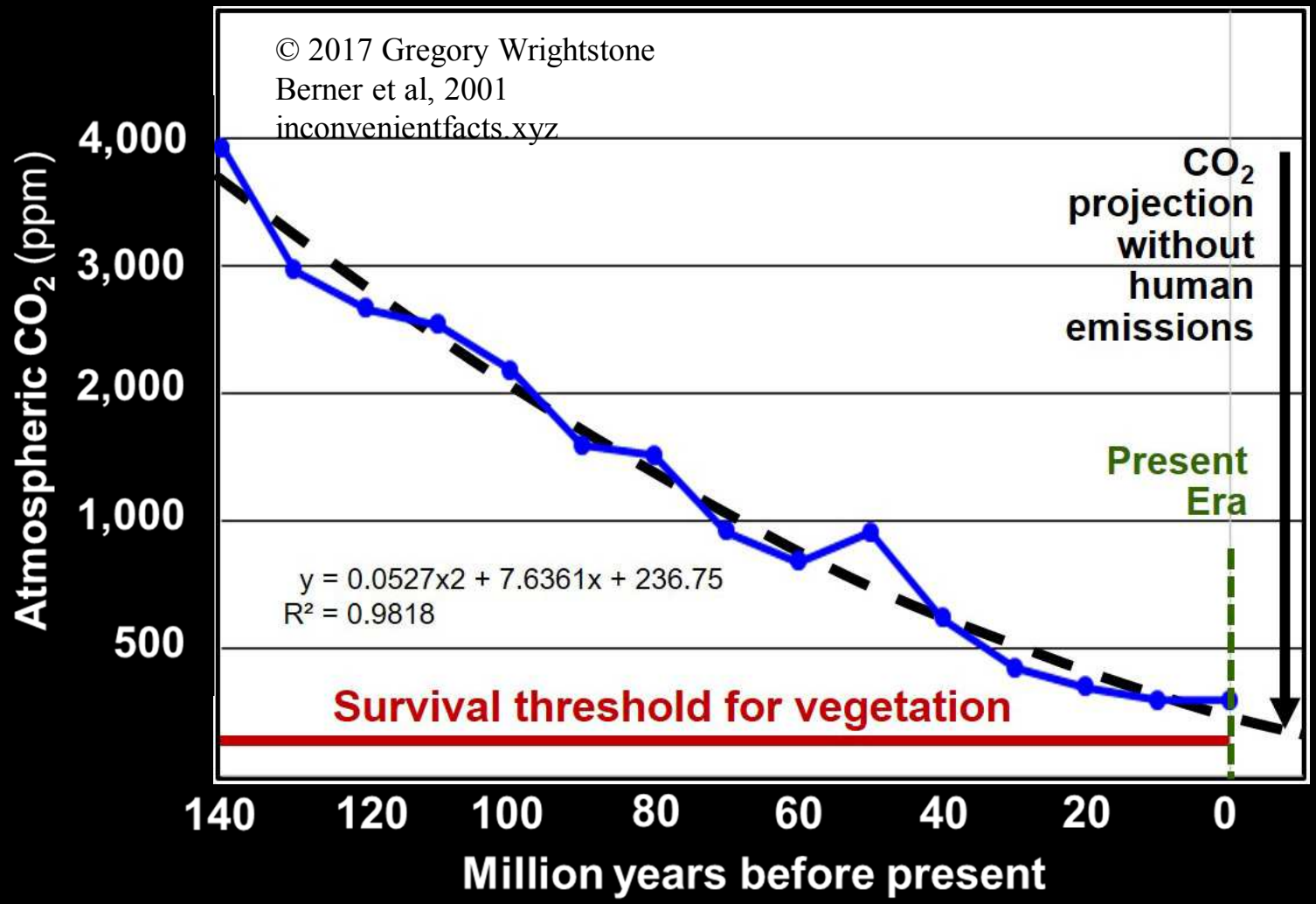
Fig I-14: Average CO2 concentration by geologic period



Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

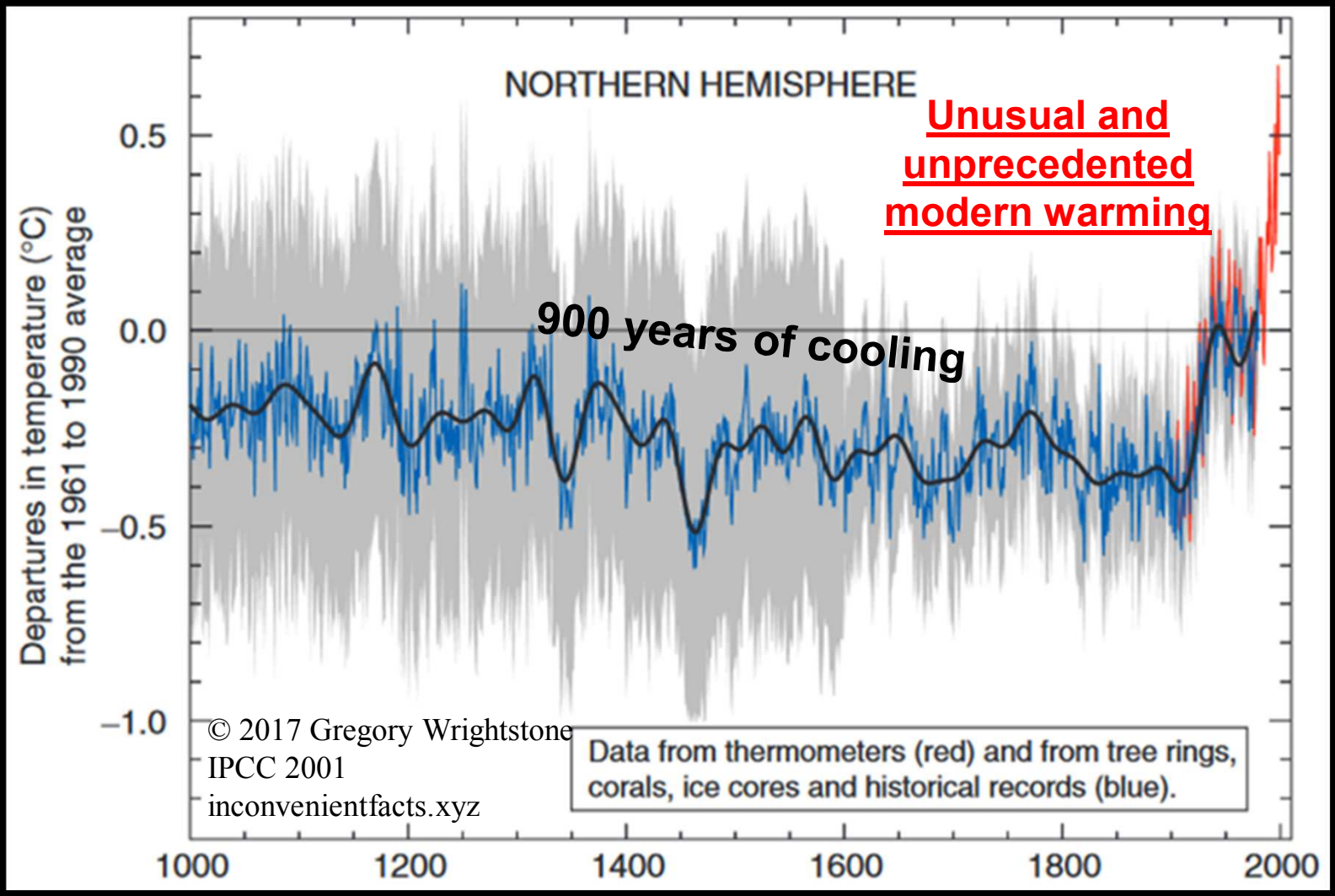
Carbon Dioxide

140 million year decline of CO_2 to dangerously low levels



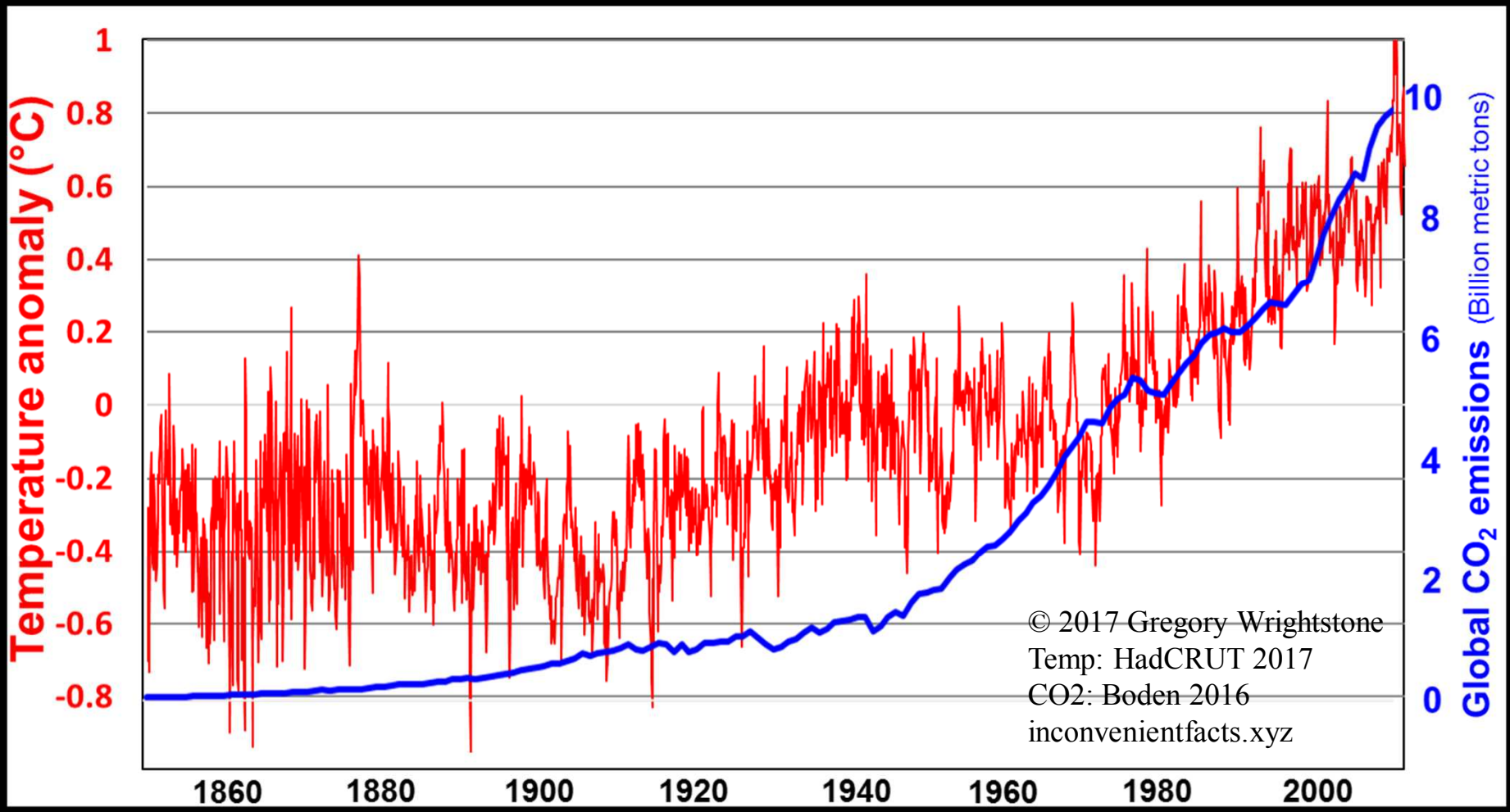
Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

Michael Mann's "Hockey Stick"
Unusual and unprecedented modern warming



IPCC (2001): Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

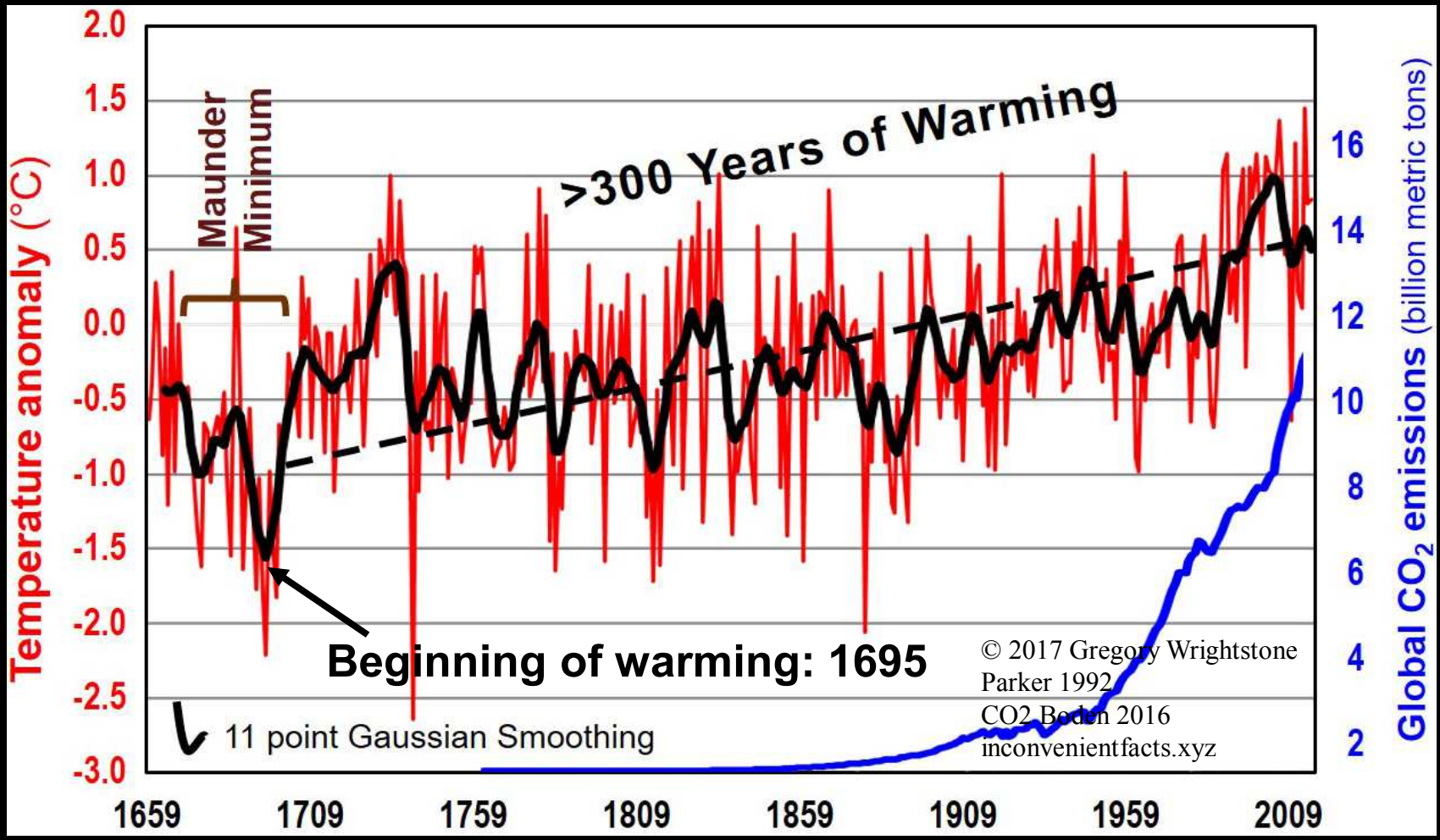
“Recent” temperature 1850 – 2016 vs. CO2 emissions HadCRUT4



Source temperature data: HadCRUT4 (2017) The Hadley Climate Research Unit (HadCRUT4) annual global mean surface temperature dataset, http://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/download.html

Source CO2 data Boden TA, Marland G, Andres RJ (2016) Global CO2 emissions from Fossil-Fuel Burning Cement Manufacture and Gas Flaring 1751 - 2013. CDIAC, Oak Ridge National Laboratory, U.S. Dept of Energy, Oak Ridge, TN, USA,

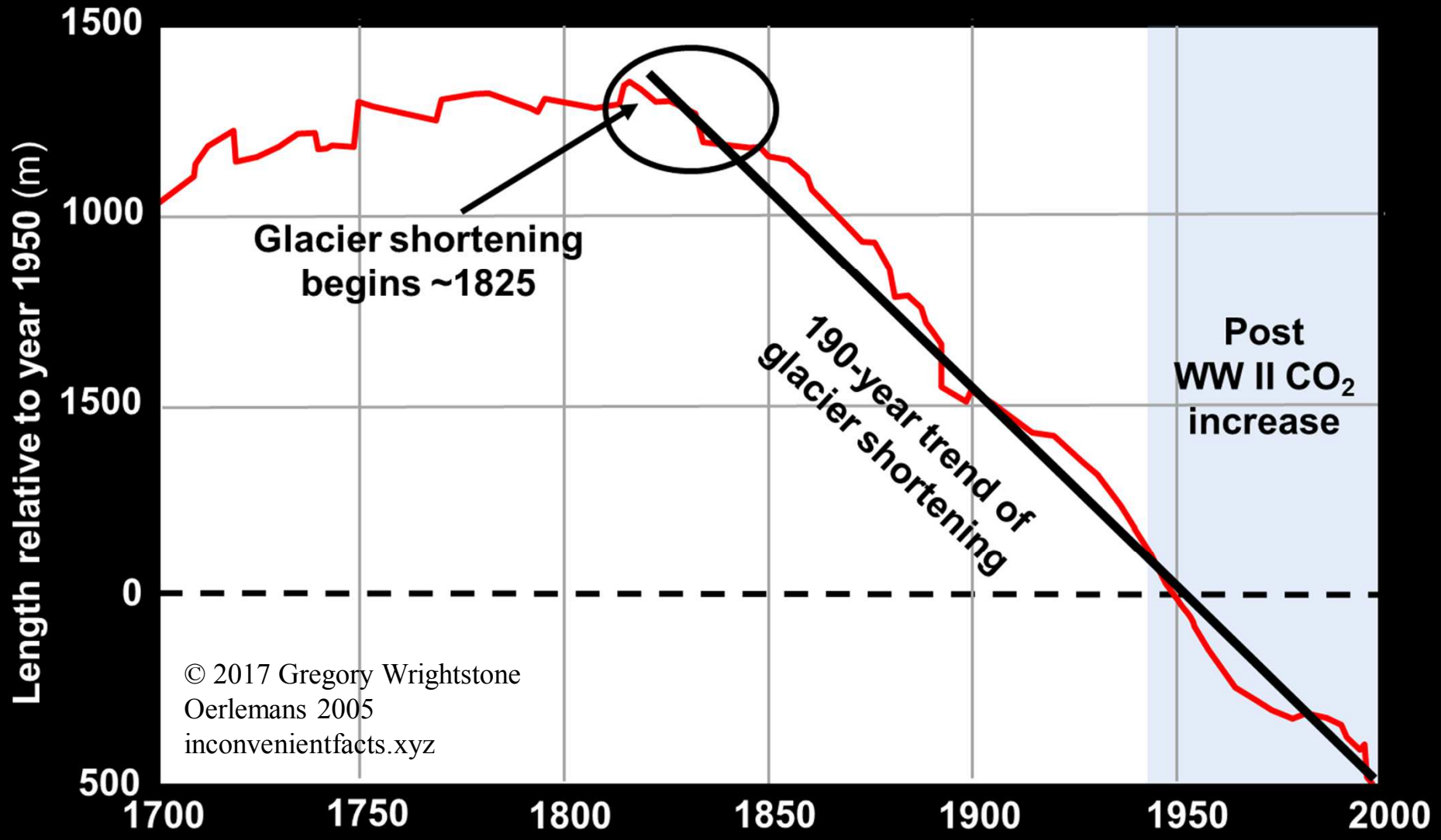
Fig I-24: Temperature history since 1659 from central England (HADCET) Beginning of modern warming trend: 1695



Source temperature data: Parker DE, Legg TP, Folland CK (1992) A new daily Central England Temperature Series, 1772 – 1991. Int. J. Clim., Vol 12, pp 317–342, www.metoffice.gov.uk/hadobs

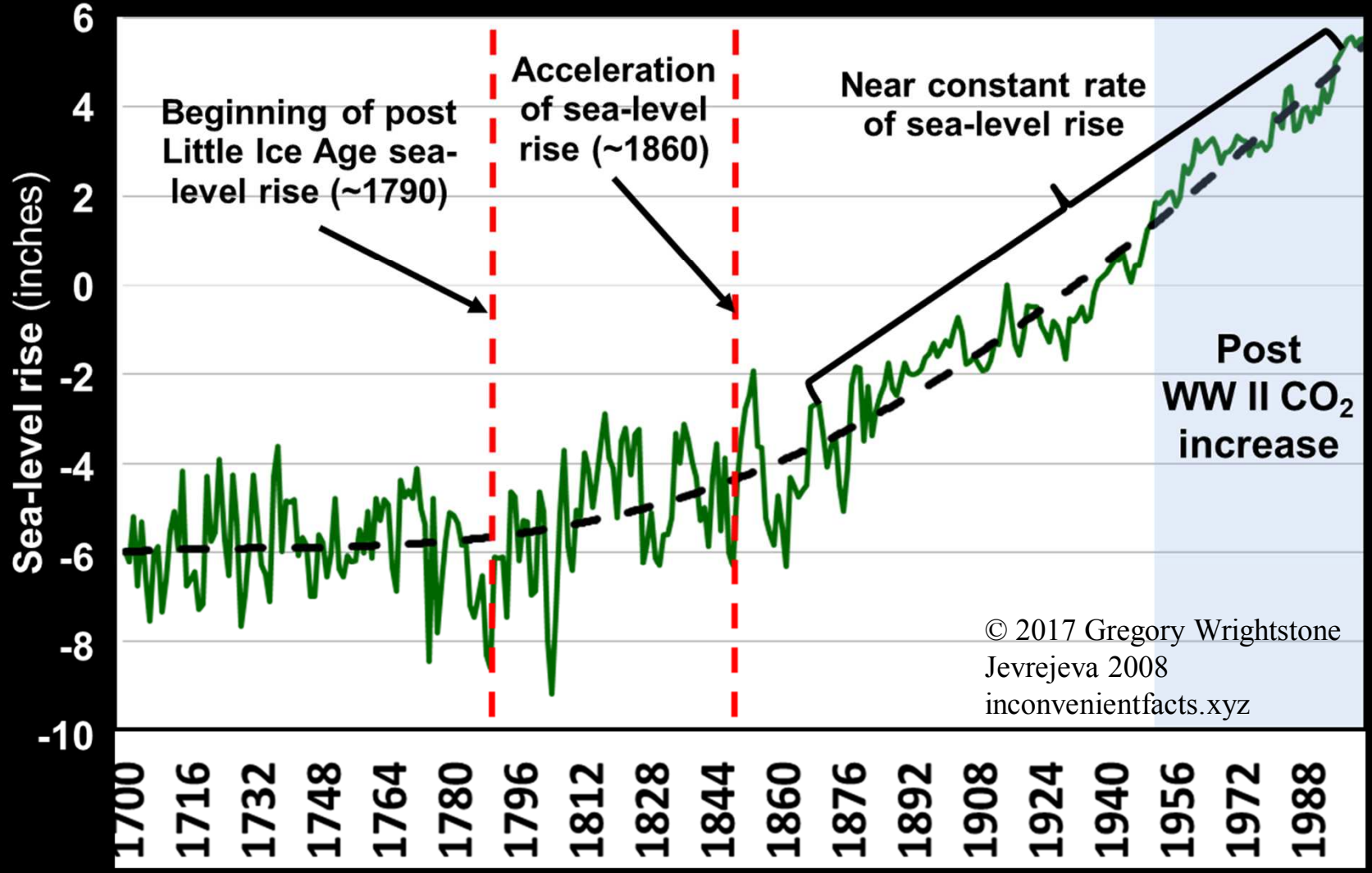
Source CO2 data: Boden TA, Marland G, Andres RJ (2016) Global CO2 emissions from Fossil-Fuel Burning Cement Mnfctr. & Gas Flaring 1751-2013. CDIAC, Oak Ridge National Lab., U.S. Dept of Energy, Oak Ridge, TN, USA,

Glacial retreat predates CO2 rise



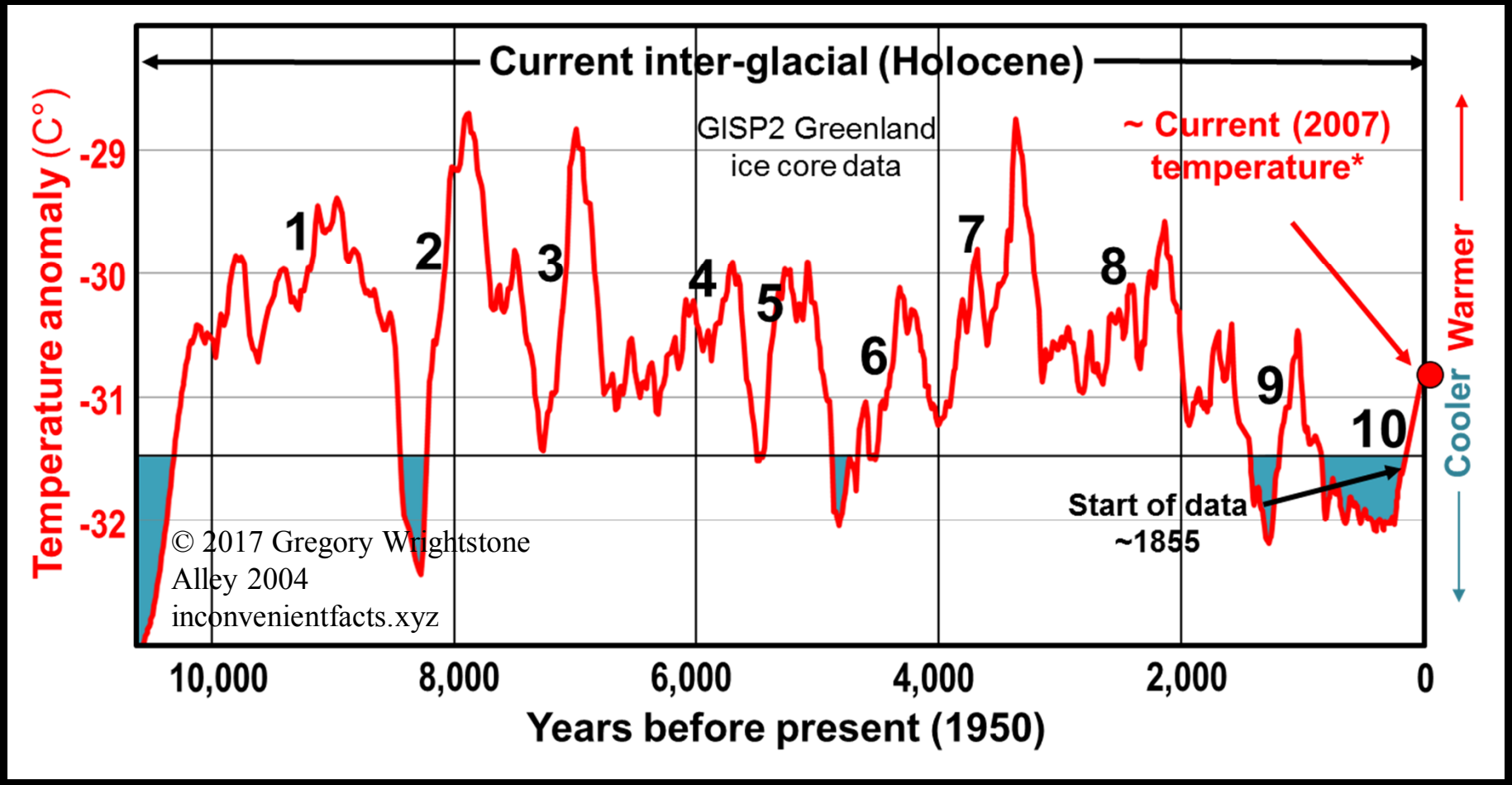
Oerlemans J (2005) Extracting a Climate Signal from 169 Glacier Records. *Science* 29 Apr 2005: Vol. 308, Issue 5722, pp. 675–677 DOI: 10.1126/science.1107046

Sea-level rise coincides with glacial retreat



Jevrejeva S, Moore JC, Grinsted A, Woodworth PL (2008) Recent global sea level acceleration started over 200 years ago? Geophys. Res. Lett., 35, L08715, doi:10.1029/2008GL033611

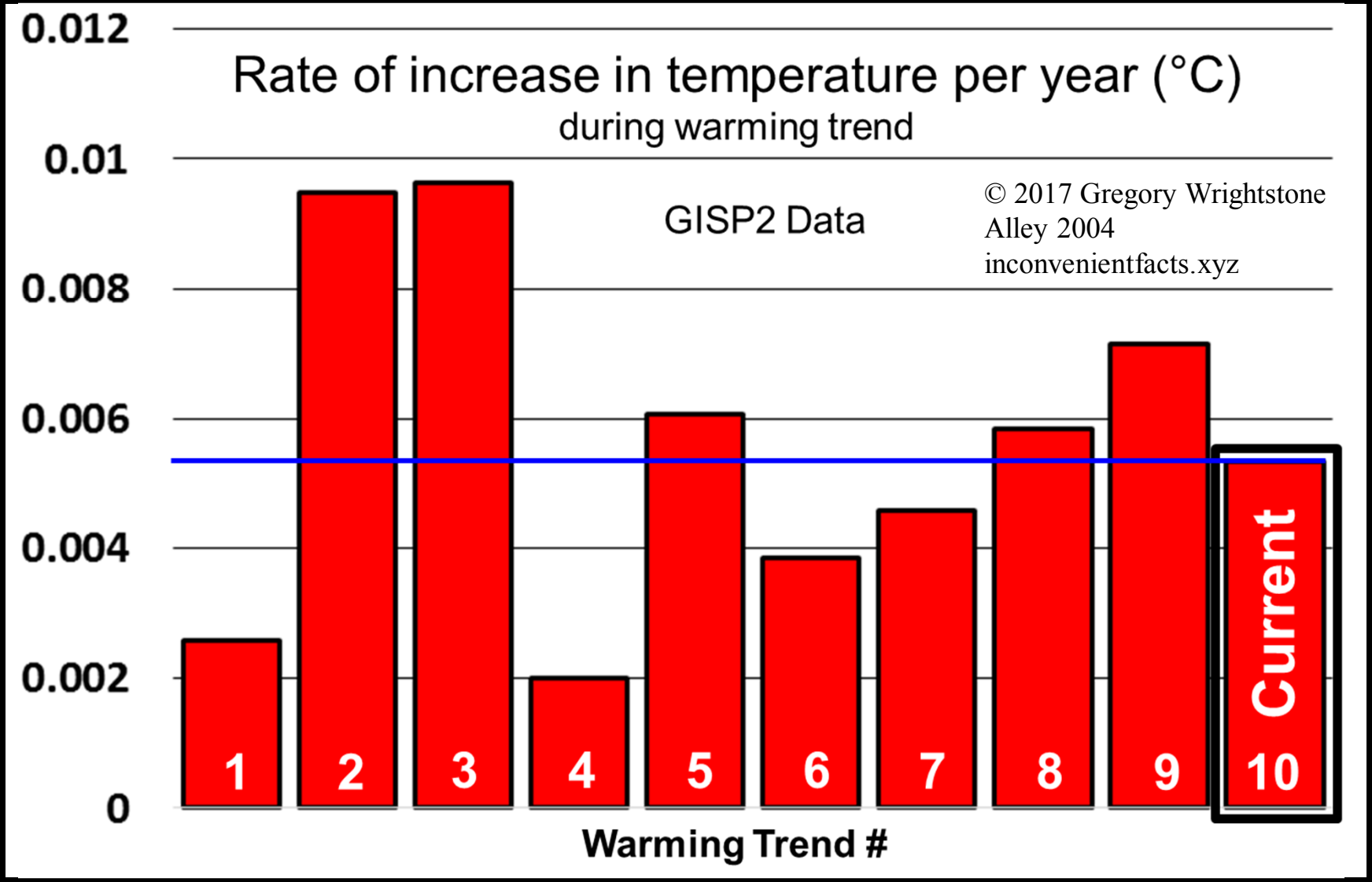
Nine previous significant warming trends are similar to current one



Source temperature: Alley, R.B.. 2004. GISP2 Ice Core Temperature and Accumulation Data. IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2004-013. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

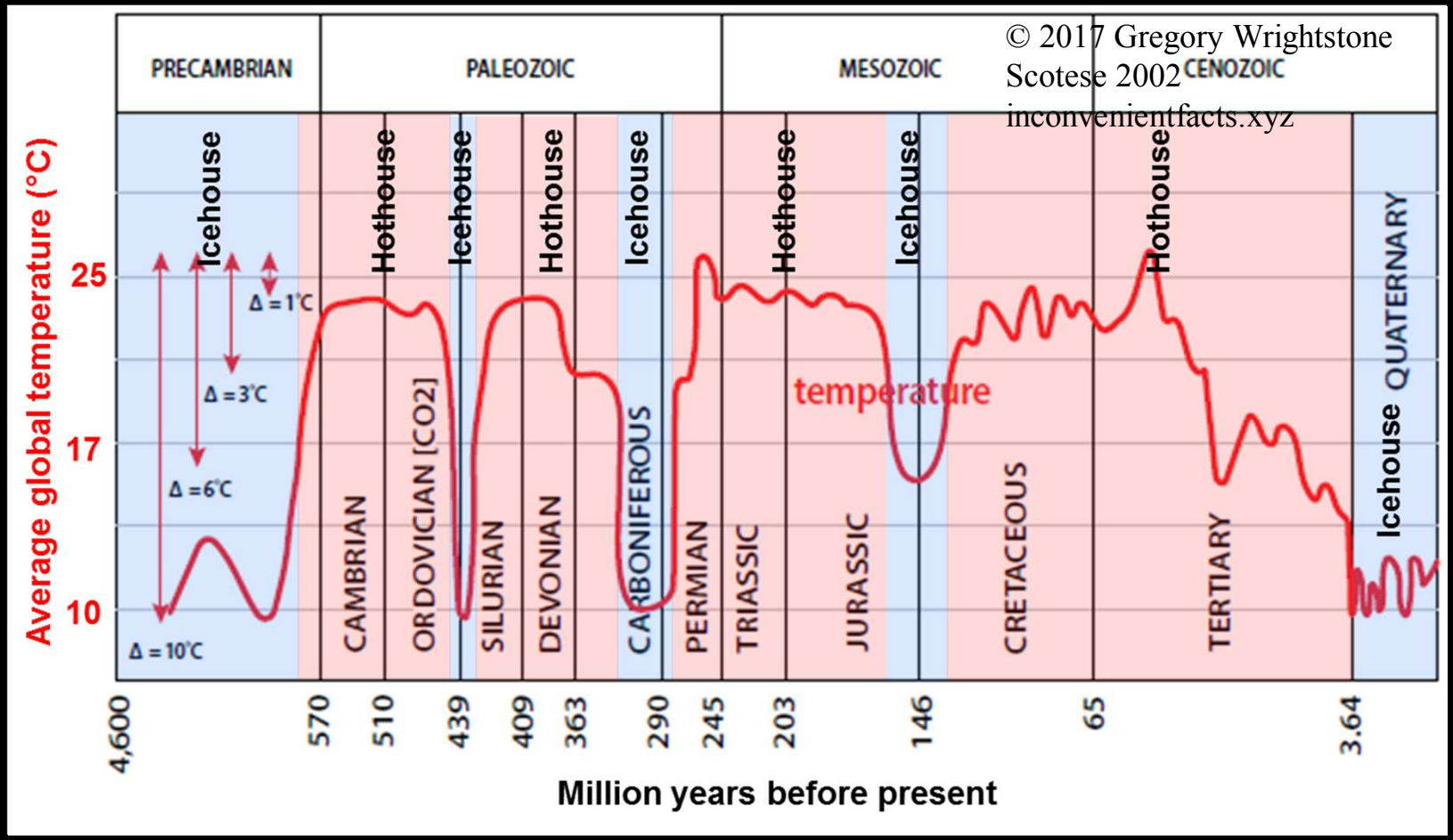
Current Temp: Box JE, Yang L, Bromwich DH, Bai L (2009) Greenland Ice Sheet Surface Air Temperature Variability: 1840–2007*. American Meteorological Society, Journal of Climate Vol 22, pp 4029 - 4049

Current warming similar to nine previous warming trends



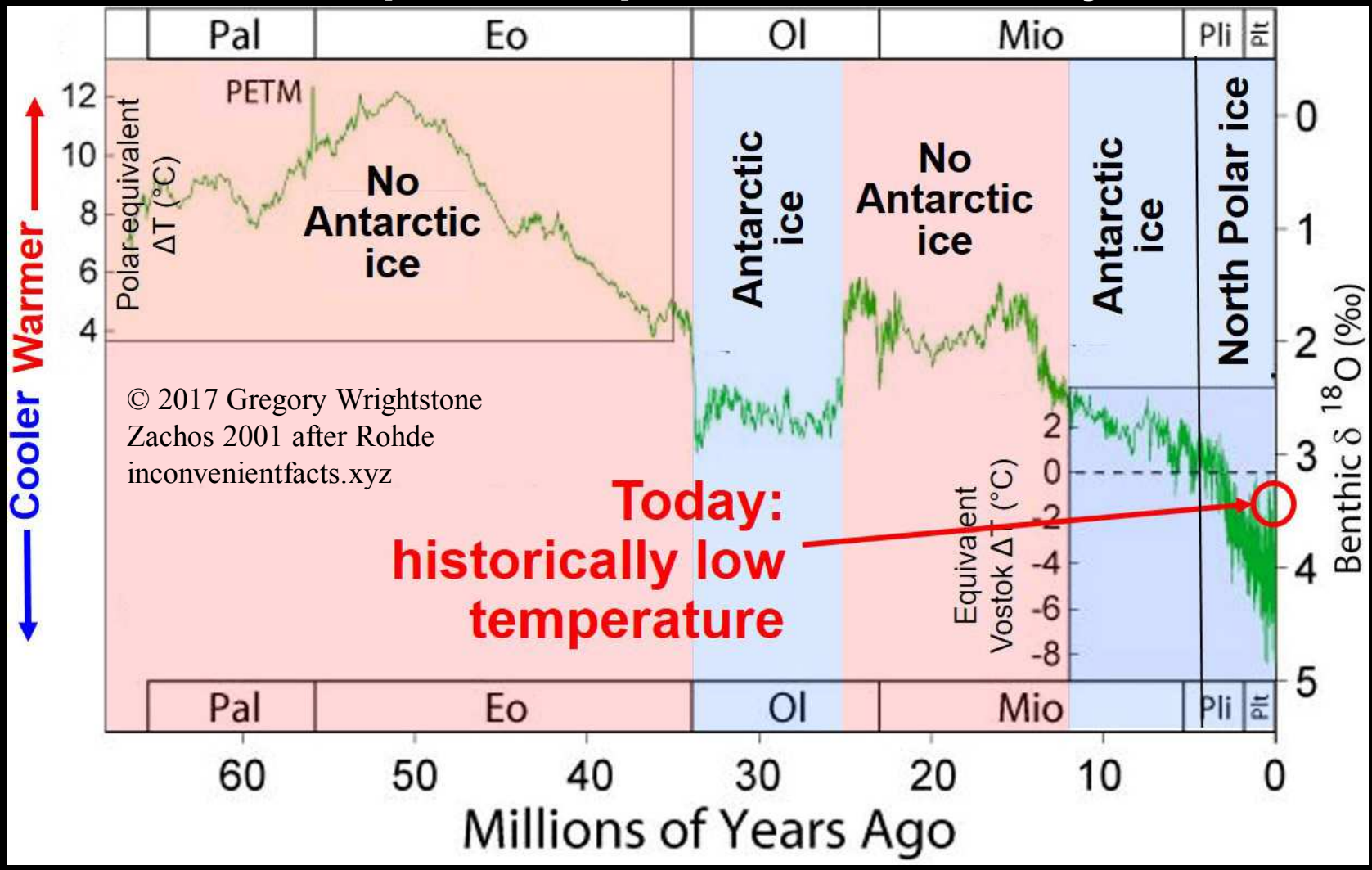
Source temperature: Alley, R.B.. 2004. GISP2 Ice Core Temperature and Accumulation Data. IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2004-013. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

Too hot or too cold
Icehouse to hothouse
4.5 billion years of temperature data



Scotese CR (2002) Analysis of the temperature oscillations in geological eras. Paleomap Project http://www.scotese.com/climate.htm

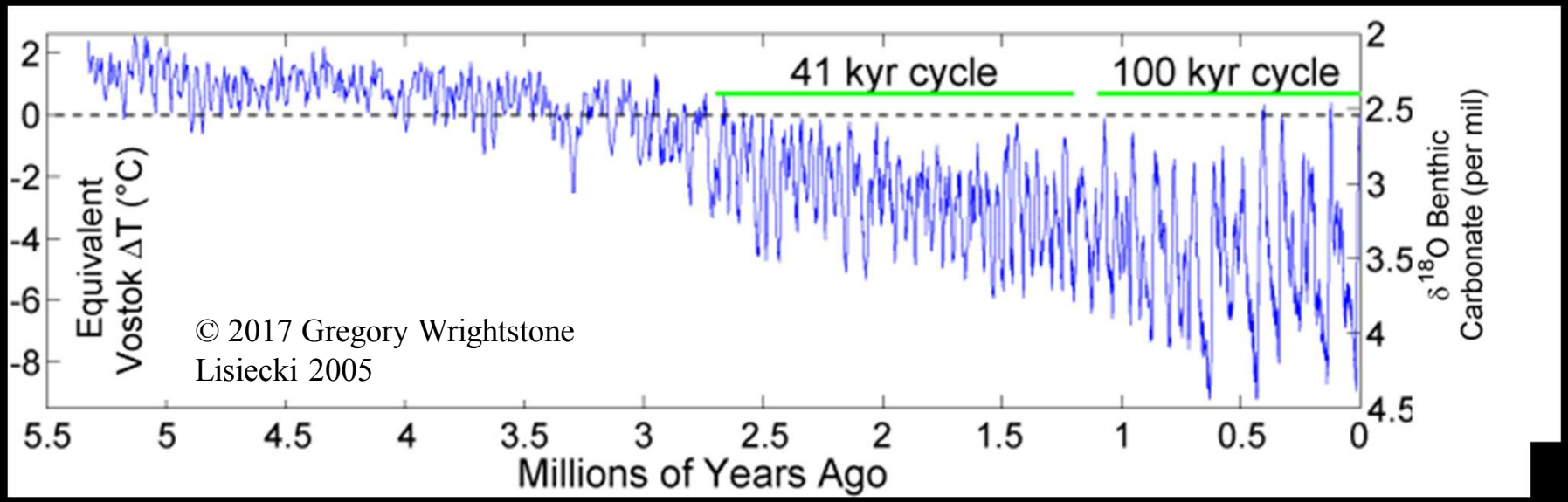
65 million years of cooling
Current period's temperatures are historically cold



After: Robert A. Rohde / Global Warming Art, J. Zachos, et al (2001) – *Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present*, *Science* 292 (5517), 686–693

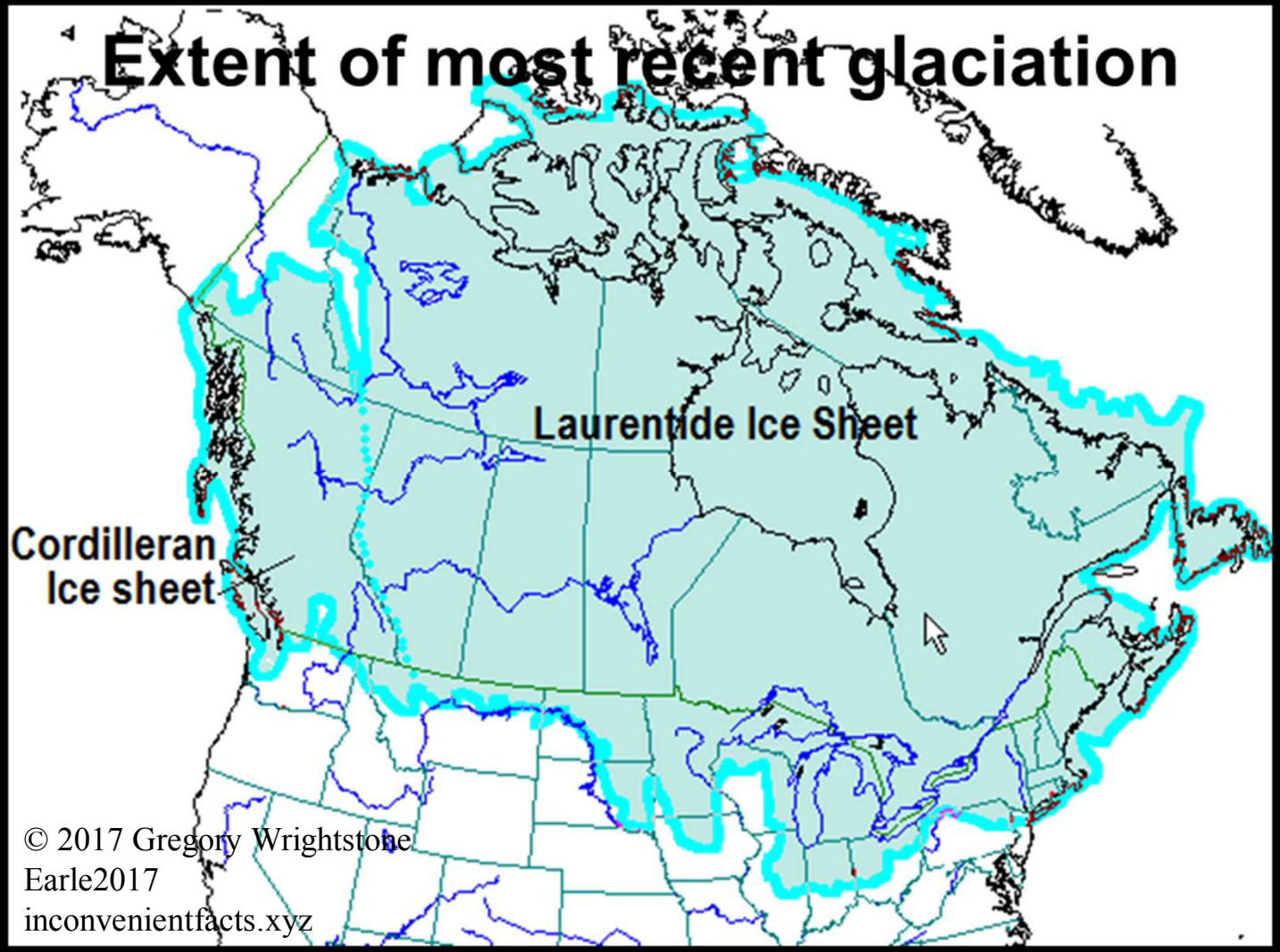
Milankovich cycles drive glacial-interglacial changes

- 100,000 year cycle: eccentricity of Earth orbit
- 41,000 year cycle: variability of obliquity of Earth's axis
- 26,000 year cycle: Earth "wobble" (precession of the equinoxes)



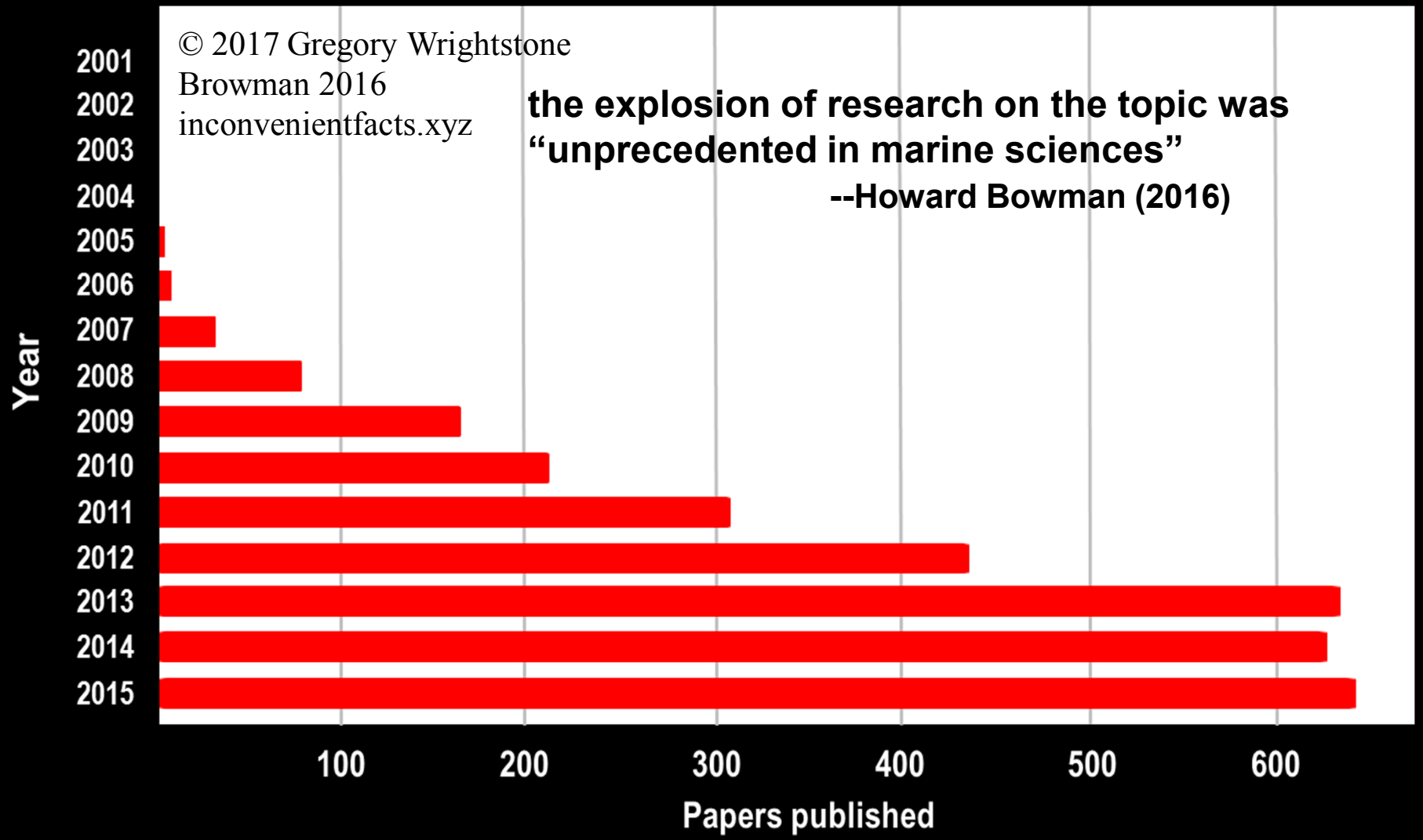
L. E. Lisiecki and M. E. Raymo (2005) – A Pliocene-Pleistocene stack of 57 globally distributed benthic δ18O records, Paleoceanography 20, 1003, image adapted from Dragons flight (Robert A. Rohde) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons

120 million persons at risk in NA alone



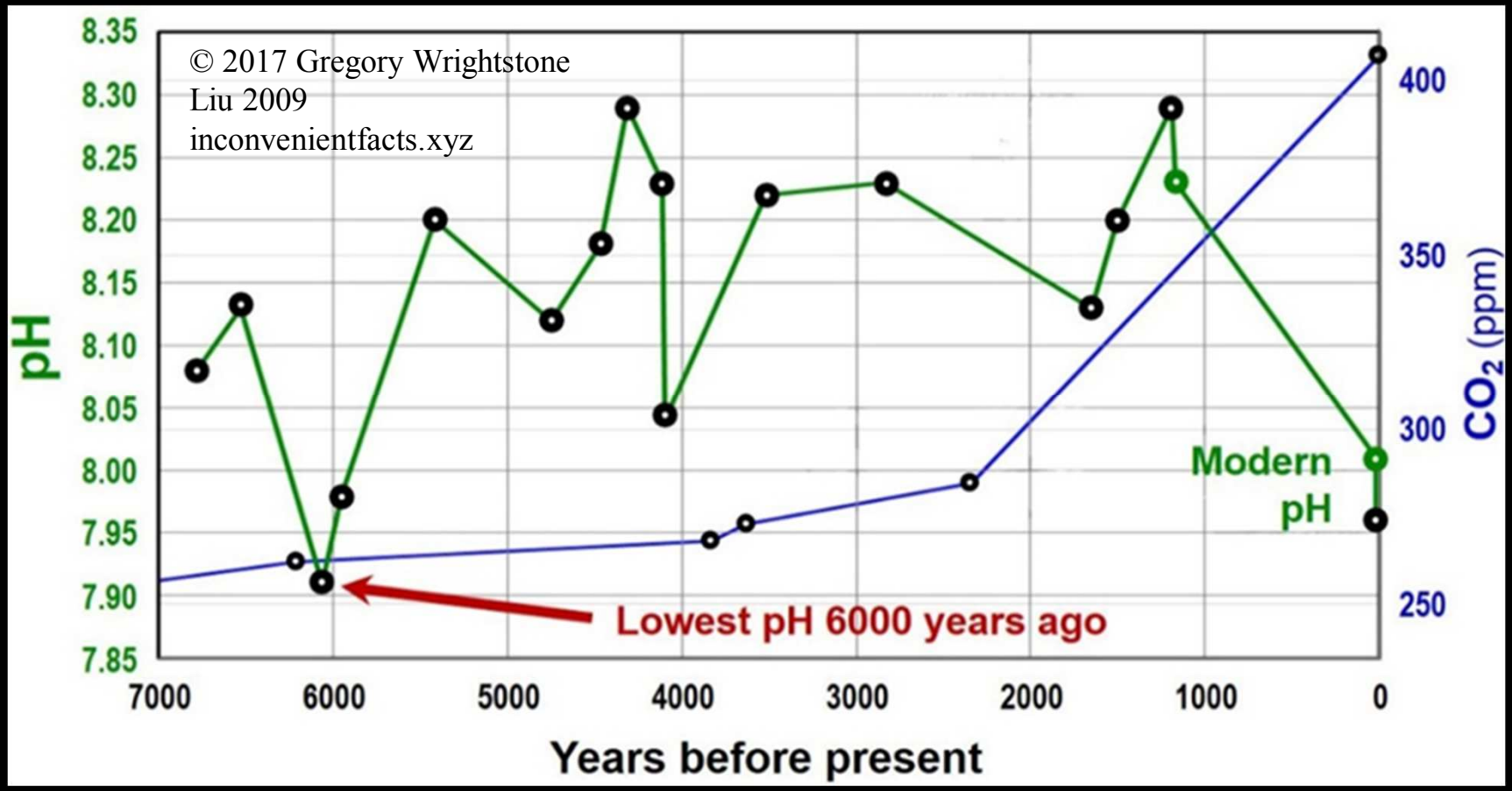
Ocean acidification

Increasing CO2 > increased carbonic acid > acidified oceans



Browman HI (2016) Applying organized scepticism to ocean acidification research, ICES Journal of Marine Science 73 (3): 529–536

7,000 years of ocean pH in the South China Sea, and CO_2



Source data pH: Liu Y, Liu W, Peng Z, Xiao Y, Wei G, Sun W, He J, Liu G, Chou C (2009) Instability of seawater pH in the South China Sea during the mid-late Holocene: Evidence from boron isotopic composition of corals, Geochimica et Cosmochimica Acta 73 (2009) 1264–1272

Ocean acidification

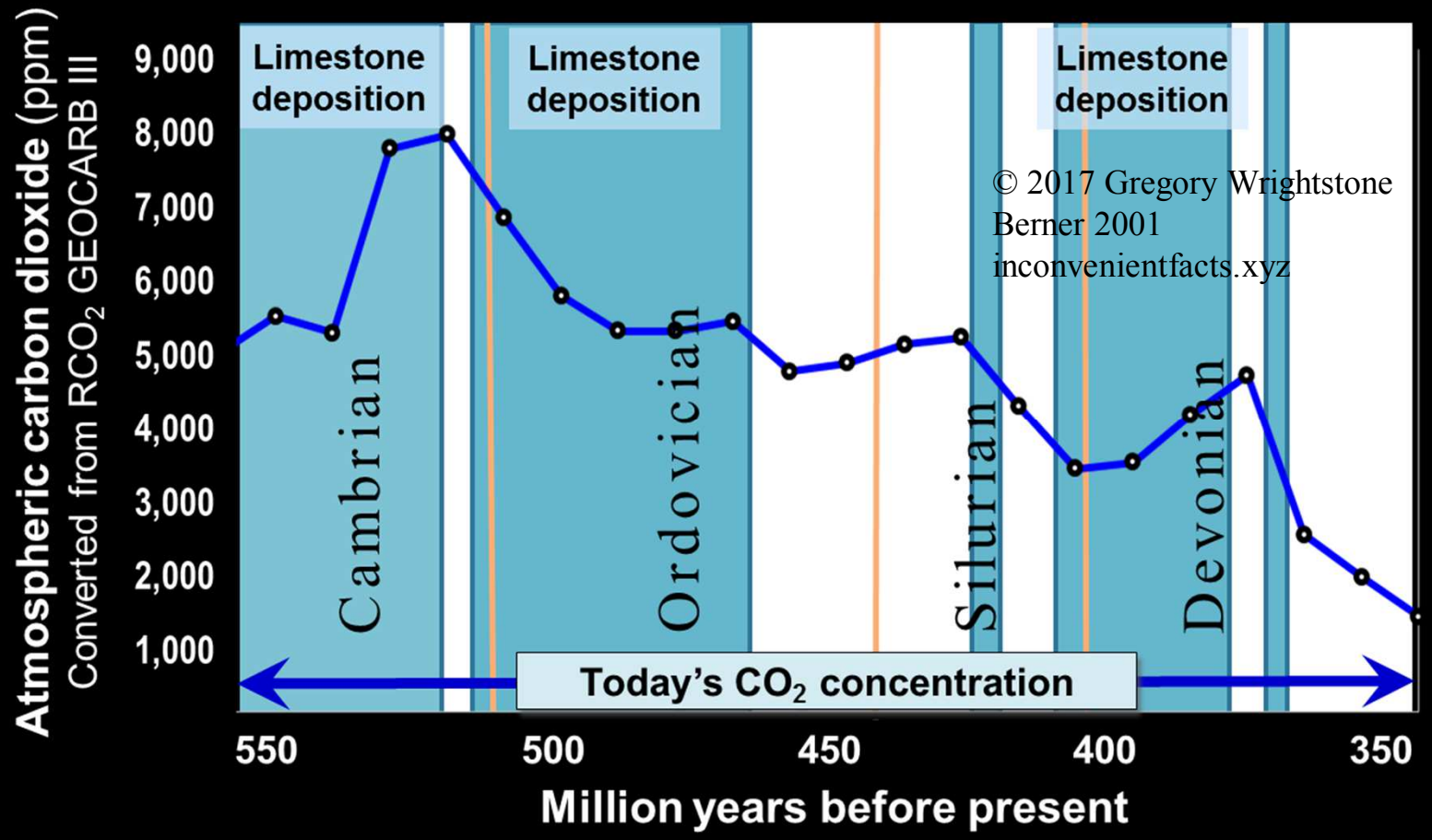
Increasing CO2 > increased carbonic acid > acidified oceans

"When CO2 levels in the atmosphere reach about 500 parts per million, you put calcification out of business in the oceans."

-- Professor Ove Hoegh-Guldberg, Director of the Global Change Institute and Professor of Marine Science at the University of Queensland

Appalachian Basin limestone deposition and CO2

No ocean acidification even at levels 20 x today's



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One of the two principles of natural justice recognized in the law of the English-speaking countries:

Audiatur et altera pars

“Let both sides be fairly heard”