COVER PAGE

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Is: Global Warming is Industrially Suppressed Middle-School Science

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Table 1 Abbreviations

AGW	Anthropogenic Global Warming
AR	Annual Review
CRU	Climate Research Unit
ENSO	El Niño Southern Ocean
ERS	Earth's Radiation Surface
IPCC	Intergovernmental Panel on Climate Change
LIA	Little Ice Age
MI	Mobile Inventory of atmospheric CO_2
MWP	Medieval Warm Period
OGW	Ordinary Global Warming
StAt	*U.S. Standard Atmosphere*
SB	Stefan-Bolzmann law
SOM	Soil Organic Matter
StAt	U.S. Standard Atmosphere

1 Key Points

1. Big Oil may be responsible for our failure to respond to global warming
2. The Little Ice Age was the first millennium of the missing "Vostok" glaciation
3. Anthropogenic Global Warming restarted the pre-Holocene T-Rise c. 1900

Global Warming is Industrially Suppressed Middle-School Science

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Abstract

The 15% of the American public that denies global warming probably used middle-school science texts in which the topic was omitted at the behest of Big Oil. We attempt to remedy this with a simple explanation of the process, in which the 33°C difference between the Stefan-Bolzmann astrophysical -18°C temperature of the solar-heated planet and the Weather Bureau's comfortable 15°C sea-level temperature is defined as Ordinary Global Warming (OGW). Anthropogenic Global Warming (AGW) is then a 2°C extension of OGW. We relate this process to the Little Ice Age, the Hockey Stick, and the implacable future course of warming. A 1.5 ppb annual drift of CO_2 from air to leaves to detritus (reversed during a T-Rise) is adequate as a driver of glaciation. We close with an adaptive example of what it will take for society to survive (i.e, reverse AGW) if we stop adding CO_2 immediately.

I dedicate this paper to the memory of Stanford climatologist Stephen Henry Schneider (1945-2010): I think I found what he was searching for.

Keywords: Disinformation, Ordinary global warming, Anthropogenic global warming, soil polymers, Little Ice Age, tallgrass-root sequestration

2 Sociological Background

Global warming to scientists and the ever optimistic IPCC world is a geophysical process well underway and affecting lives. Global warming to much of the U.S. is a manufactured political argument in aid of protecting profits. Global warming to governments is either confusing (and needs more study) or understood (but offers no economically feasible solution (and is best left for the other party to deal with).

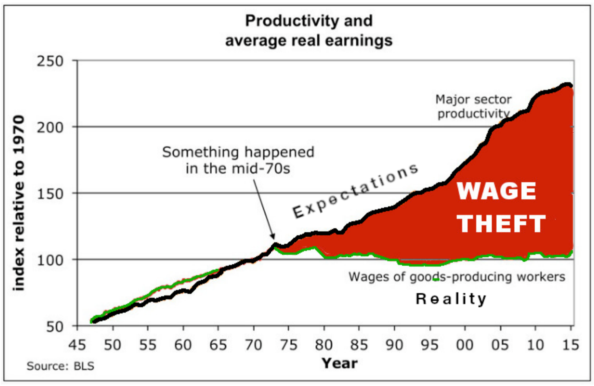

Fig. 1 Wage Theft. Data from the Bureau of Labor Statistics analyzed by *The Economist* shows that trickle-down economics works as intended and not as advertized. We were told it would increase employment and economic growth, but 50 years of experience showed that '[R]eal GDP per capita and the unemployment rate are unaffected by significant reductions in taxes on the rich" (Hope & Limberg 2020) If your expectations and reality differed this much, you'd be angry too!

Global warming in reality is a 40% change in an IR-sensitive atmospheric component with culture-breaking, extinction-level, consequences. There are things we can and should be doing about this. There are things we need to understand before we can generate the national political will to do what needs to be done.

2.1 Texas, Textbooks, and Denial

It may well be that 25% of Congress is unable or unwilling to acknowledge global warming (Climate Deniers 2021), but it is unlikely that 15-30% of American voters (Gounardis, Newell, 2024) are hopelessly stupid. Their denial of science and reality is not a spontaneous rejection of common sense and respect for professionalism. It is the result of an organized program (McGreal 2021) of lies to, and manipulation of, ordinary people angered by the faceless wage theft of Fig. 1 and a constant barrage of slanted questions and disinformation on social media whose income depends upon clicks near controversial topics. The "something" of Fig. 1 that happened in the mid-70s includes Reagan's trickle-down trickery (2020), the Powell Memorandum (1971) advocating that the minority party should concentrate on controlling the judiciary (for which Powell was rewarded with a seat on the Supreme Court), and the establishment of right-wing paper mills like the Heartland Institute.

We are learning to distinguish between *Misinformation*: "False information that is spread, without intent to mislead" and *Disinformation*: "Deliberately misleading or biased information; manipulated narrative or facts; propaganda", used with great success by the Russian state since 1917, and with particular effect on the election of Putin's nominee for U.S. President. Targets of racial discrimination make a similar distinction between *Diseducation*: "Teaching deliberately misleading or biased information; manipulated narrative or facts; propaganda" and "*Miseducation* speaks to the impact, but diseducation exposes the intent of the education system [to marginalize and reinforce oppression]" — where the bracketed phrase is too restrictive and can easily be replaced by "[to perpetuate a traditional practice or profit]"

It is likely that the middle-school science textbook of deniers (if they had one) was deliberately disinformative about global warming, leaving them unequipped to evaluate changes and expecting the continuity implied by a conservative milieu. Those who recall Jefferson's description, "the whole art of government consists in ... being honest" will be disappointed to find that the facts of global warming have been deliberately kept out of schoolbooks at the behest of lawyers for Big Oil sitting on Texan school boards (Worth 2020), ensuring that nothing that might affect Big Oil's profits was mentioned. (Texas has an exaggerated influence on the textbook market.)

Nor is it just middle-school students who are intentionally disinformed. I whetted my global-warming hypothesis on tutorials for the Quora website, and discovered a strange coincidence: the comments offered by the few whose qualifications included a BSc followed by an MBA wrote as though the laws of science were, like the laws of Congress: adjustable. My sample was small; if I were 60 years younger, I might follow it up myself, because (Jefferson again) "experience hath shewn, that ... those entrusted with power have, in time, and by slow operations, perverted it into tyranny; and it is believed that the most effectual means of preventing this would be, to illuminate, as far as practicable, the minds of the people at large" I hope to do that for global warming with a straightforward approach to the problem.

2.2 Red-herring Disposal

Global warming is alarming — and there are 2 responses to reduce the resulting discomfort. The lazy way is to cry "hoax" so it can be ignored. The responsible way is to compare the idea with what we know. The first step in comparing is to show that the candidates from social media — it's the sun, or volcanoes, or the ocean — can be dismissed. This we do with Fig. 2, which compares observed temperature (the spiky black line in the upper graph) to a reconstruction (the orange line) combining recorded data for these 3 potential drivers with the known anthropogenic contribution. ENSO (El Niño Southern Oscillation) is monitored by buoys across the central Pacific.

Figure 2 shows that computers can tell us what is going on. That they can also suggest ways for society to survive the century (see the IPCC's AR6) is a bit misleading, since computers have been showing this for 50 years (Meadows 1972), Congress has rejected the necessary steps as unwarranted, expensive, and disruptive of campaign contributions. Meanwhile the problem becomes more intractable and expensive every year. Swiss Re — as conservative an institution as exists — predicts climate-change related annual losses of $23 trillion by 2050 (Flavelle 2021) That's half the investment in the U.S. stock market. It is time for serious action — but what should that action be now that the obvious approaches are too little and too late? (I do not mean to disparage individual action: I belong to the bicycle/solar-energy crowd — but the Keeling curve keeps climbing [https://keelingcurve.ucsd.edu]).

Figure 2 is a short-term view, relevant to political arguments about Anthropogenic Global Warming (AGW). Corrective action requires an understanding of the unprecedented geophysical history of the last 150 years. The initiation of global

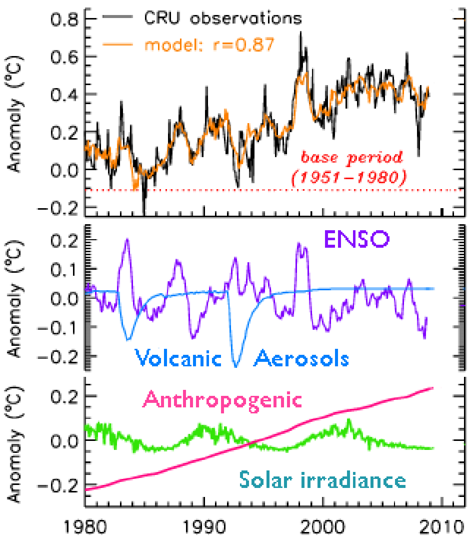

Fig. 2 Matching Theory to Data. Upper panel: This 30-year comparison by Lean and Rind (2020) reconstructs the temperature record (orange line) by combining data from ENSO oceanographic buoys, upper-atmosphere shading by volcanic dust, the 11-year solar cycle, and an almost perfectly linear anthropogenic contribution, to match the observed temperature (black) All of these are monitored constantly and automatically. The sharp spikes in the black line of original data remain unexplained. However, the r=0.87 indicates that the model explains $r^2 = 76\%$ of the data, close enough to qualify for the 80% Model. There is no indication that the residuals (the differences between the orange and black lines) show a pattern. (unless it is that the CRU observations are subject to spikes) **Lower panels:** These data sets were combined to produce the orange curve. Honest main-stream media would have publicized this information as a civic obligation, but they get more viewers with controversy.)

warming was too novel to be anticipated, too subtle to be identified, too slow to be alarming, too various to be interpreted as anything but random — and too unlikely to be believable. It also came at the end of an interglacial unlike any of its predecessors.

It is easier to eliminate drivers than demonstrate them. The problem of accounting for the energy used to warm the Earth is the loss of precision involved with subtraction of large numbers where the difference is comparable to the precision. We receive 1368 W/m^2 from the sun and keep 1 to warm the ocean.

3 Geological Background

Interglacials tend to be spikes. making the 12,700-year Holocene unique. It spent some time melting remaining ice before reaching a rounded maximum 7500 years ago. Since then it cooled slowly until 900 CE, when it accelerated (Kaufman &31a 2009). The Holocene includes the discovery of the 4 critical processes that define our present: Greenhouse Effect (Eckholm 1901), Modern Warming (1960s), Delayed Glaciation (2003), and Aborted Glaciation (2024) — all of them our doing. The first two are familiar; the second pair need explanation. §2.1 lays out the course of a normal glaciation for background.

3.1 The Normal Glacial Cycle

Forgive the abruptness of this list: there is a lot of ground to cover, and we need to establish the expected sequence. §3 describes the differences that make our Holocene exceptional.

This is an idiosyncratic view of an idealized 100,000-year glaciation (or T-fall), followed by a 10,000-year T-rise, applicable to the 800,000 years of the "Vostok" data leading to the Holocene. Earlier, too many parameters were too different for meaningful comparison. Strictly speaking, "Vostok" is the Russian Antarctic station at the pole of inaccesability which produced a 3-km ice core with annual layers of proxy climate data. There are cores from other sites in Antarctica and Greenland and I use "Vostok" as shorthand for all their data, including eight cycles with high correlation between Antarctic temperature and CO_2 (PAGES 2016). Its last 4 peaks are shown in Fig. 4's inset for context. There are 20 years of overlapping agreement between the ice (firn) record and the Keeling curve. Caveat: These cores, and others from the sea floor, offer great insight into a "300 ppm world". But that insight may not have much to do with today's "425 ppm world". The system is exploring ways of coping with new conditions, and is just as confused as we are.

3.1.1 Step by step

1. Hypothesis: The mobile inventory (MI) of CO_2 is the parameter that best characterizes a cyclical glaciation. (This is just another version of (Lacis 2010): "CO_2 is the control knob of climate.") Each Vostok peak has a slightly different MI $<$ 300ppm.
   (a) The Croll (1875)-Milankovitch (1941) hypothesis of small orbital changes from interplanetary gravitation explains only 20% of the periodicity of glaciations (Wunsch 2004).
   (b) From the steep T-rises and slow T-falls, it appears that while the T-falls are driven, the T-rises continue spontaneously, after initiation by Milankovitch at 65°N.
   (c) A T-fall should be exponential; it is quasi-linearized by the frequent interruptions.
   (d) The high noise level of the data suggests macro control at a distance and micro control (noise) locally.
2. At the peak of an interglacial (e.g, 7500 years ago, mid-Holocene), all 265 ppm (https://scripps.ucsd.edu/bluemoon/co2_400/co2_10k.png) of the current MI are in the atmosphere.
3. Vegetation flourishes; temperature falls. Linearized annual CO_2 removal is $\sim$ 120 ppm of the MI in, say, 80,000 years. 120/80,000=1.5x10^{-3}ppm/yr, or 1.5 ppb/yr, *which is itself noise* unless it is consistently repeated. Where does the MI go? It must return smoothly during a T-rise.
   (a) Classical suggestions were oceanic CO_2 system (Broeker & Peng 1987), methane clathrates in tundra and Arctic Ocean shelves (Macdonald 1990), and trees (Zeng 2003). Sigman & Boyle (2000) suspect the Antarctic gyre. Photosynthesis (land and sea) would seem to be the most active driver.
   (b) The annual northern hemisphere tree-leaf cycle is $\sim$ 5 ppm (Keeling curve).
   (c) 1.5 ppb (annual removal)/(5000 ppb (annual vegetation)=0.3/1000=0.03% of annual leaf-fall would need to resist decay to store all the missing MI. But why would it release during a T-rise?

(d) There are 2 more large unquantified reservoirs: soil, for roots and humic (insoluble) polymers, and the ocean for long-lived fulvic (soluble) polymers (Zark, Dittmar 2018) (Jiao &10a 2019).
(e) Sugar is the monomer of cellulose, and phenol of lignin, the predecessors of the humics and fulvics of soil. Inedible to bacteria of the Carboniferous, they gave us coal and oil before fungi learned to eat them.
(f) Glomalin, the 3rd complex irregular polymer, is made by arbuscular mycorrhizal fungi on root hairs (Wright, Upadhyaya 1996), and transfers mineral nutrients to plants in exchange for sugar (Parniske 2008). It is long lived, and perhaps the largest fraction of soil organics (Hayes &2a 2017), suggesting that it might be useful for permanent sequestration (Irving &3a 2021).
(g) The world average root/shoot ratio for woody plants is 0.25 (Huang &12a 2020); for tallgrass (e.g., *Thinopyrum intermedium*) it may reach 2.5 (Sainju &3a 2017).
(h) It seems we have an embarrassment of choices for reservoirs, processes, compounds, reactions, and rates — whose details are poorly known — to answer "Where does the MI go."

4. Glaciation is a delicate balance. Nearly 500 papers address the 10°C Dansgard-Oeschger interstadial oscillations in Greenland ice-core data, most offering complex hypotheses and some settling for "stochastic".
https://www.science.gov/topicpages/d/dansgaard-oeschger+d-o+events
5. The T-fall and tree growth eventually slow. Temperatures are down 10°C at the poles, 5° in the Temperate zone (Hansen &9a 2008). The MI is down to 140 ppm.
6. Everything sits and waits for a Milankovitch warming at 65°N to release MI CO_2 from its northern reservoirs.
7. Milankovitch willing, insolation warms the Northern Hemisphere, and after a 500-year lag in the SH, CO_2 rises to warm Antarctica.
8. Bacteria and fungi, revitalized by warmth, chew up tree trunks and soil organics. Clathrates melt. The ocean re-"equilibrates".
9. 10,000 years (or less) gets us back to an interglacial, with the MI restored.
10. This reversible cycle is more remarkable than it has been given credit for.
11. The only new ideas here are the limited MI of CO_2 (the system *acts* as though it respected this limit), and the delicate balance of a glaciation (item 1b). Item 3 ,"Where does the CO_2 go when it goes away?" is still up for debate. The soil hypothesis was a surprise.

4 The Exceptional Holocene

If there is anything that leaps to the eye in the inset to Fig. 3, it is that the final peak cannot be explained by the others. The white line overwriting the noise of the main graph shows that the temperature indeed headed down for a full millennium before it was overruled. But we didn't notice even that. The first half of the downturn was masked by an intrusion of warm Atlantic water into the Nordic Sea. This was originally misidentified as a global event (the Medieval Warm Period) with farming in Greenland and grapes in central England (Lapointe & Bradley 2021). The tag end of the millennium was chilly, but too short to consider real.

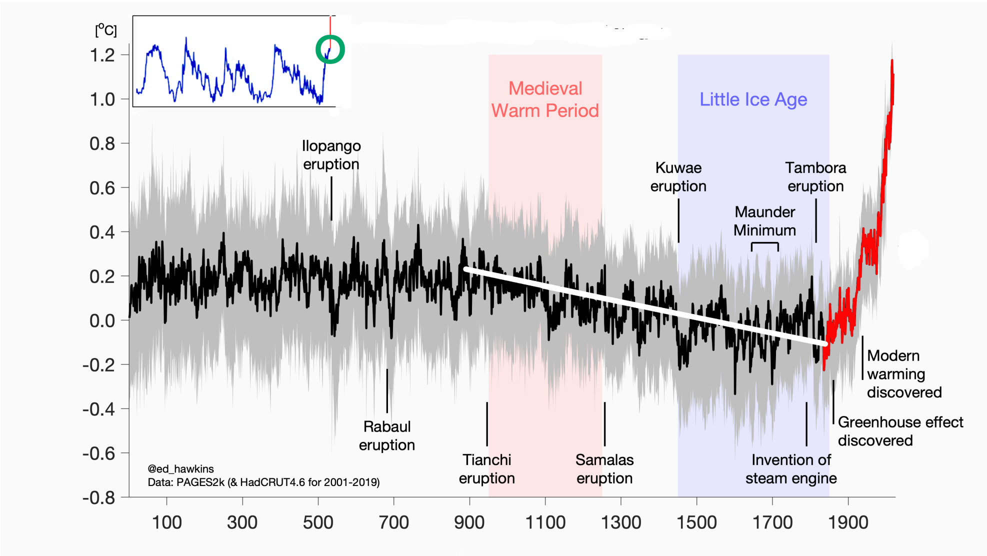

Fig. 3 The Hockey Stick as Glaciation. The inset sketches the last 400,000 years of the 10°C Vostok oscillations for context. We are now at the top of the red lines in both graphs. The larger graph expands 2 millennia at the center of the green circle. The white line is my suggestion for the abruptly terminated Final Vostok Glaciation. (Hawkins's annotations were addressed to a time when social media were still insisting that global warming was a hoax by volcanoes or the sun.)[This figure is consistent with IPCC AR6 SPM Fig. 1.]

The T-rise since 1900 is unprecedented and offers challenges for which we are unprepared. The average politician of the last half-century hasn't had a clue about Fig. 3, and most of them seem unaware of it. Scientists can at least make educated guesses; and that is what I will now attempt, to explain the white line and the red rise of Fig. 3.

Table 2 Unnoticed Episodes of the Holocene. These were major events with nearly undetectable causes. The CO_2 column asks about the sign of CO_2 change and its source.

START	**POPULAR NAME**	**EVENT**	**CO_2**
-8000	Golden Age/Garden of Eden	Extension of Holocene (Ruddiman)	+MI
900	Little Ice Age	Initiation of Final Vostok Glaciation	–trees
1900	HockeyStick	Abortion of Final Vostok Glaciation	+New

4.1 Golden Age

The principal lesson of the Holocene is how ill prepared we are for the coming Anthropocene. It was a gentle epoch, offering lessons in planetary management which might have prepared us for the hard times ahead. In particular, there were critical moments whose import we missed out of simple naïveté. Three events — all phenomena conveniently blamed on the blind forces of Nature — are collected in Table 2. In all cases, I submit that changes in CO_2 were the direct cause of the event, and two of them were ours.

There is little doubt about Ruddiman's (2003, 2015) hypothesis that the Anthropocene started early. 8000 years ago, farmers in the West cleared land by burning forests, and 5000 years ago built methane-producing rice paddies in the East. This evidently returned enough CO_2 to the atmosphere to maintain a constant temperature. If you know to look for this return, it can be seen halfway through the flat section of SIO's Keeling Curve 10k plot (https://keelingcurve.ucsd.edu). Forest burning and bacterial methane countered sequestration of the MI for 11,000 years.

The Mid-Holocene optimum — when all of the MI is in the atmosphere and the Northern Hemisphere is enjoying glorious springs and gentle winters — is often seen as a fortuitous bit of fine tuning which granted us a comfortable Holocene. Abrahamic religions credit it to a benevolent deity, and it is the logical source of all the folklore of the Golden Age and the ideal green and dewy world described by the desert dwellers of the Holy Land. with tribal memories of better times.

4.2 The Little Ice Age

Current dogma says the LIA was not a global event, but a localized cold spell (as in the Alps, Andes, Rapa Nui (Hunter-Anderson 1989), New Zealand, Alaska, Patagonia, Iceland, ...). Mathes (1939) introduced the name after surveying the pristine glacial moraines of California's Sierra Nevada.

Neukom &4a (2019) report "the putative Little Ice Age — is most likely to have experienced the coldest temperatures during the fifteenth century in the central and eastern Pacific Ocean, during the seventeenth century in northwestern Europe and southeastern North America, and during the mid-nineteenth century over most of the remaining regions" , therefore it wasn't real. But how does this differ from the first millennium of the other Vostok glaciations? Am I alone in suspecting that glaciations begin as localized cold spells and only slowly become mile-thick ice caps?

Some may recall an old video, "In Search of the Coming Ice Age" (Miller &3a, 1978). Realizing that glaciations were recurrent events (Penck 1901) and suspecting that one was long overdue, 4 climatologists explained their thinking and their efforts to understand what was not happening. Today there are a number of disinformation books making defamatory fun of these perceptive scientists for "seeking grants: if a coming ice age doesn't work, try global warming" None of the presumably subsidized right-wing authors understands either the science or the scientists' motivation (Curiosity, Reputation, and Ethics). The best they can do is to project their own approach of prevaricative perseveration in pursuit of profit. One of the authors of the video was a sometimes colleague, and I can vouch for his absolute scientific integrity — and he was exactly right. Nobody then understood the driver of glaciations, and the glaciologists had every reason to wonder what unknown process was at work. Available data was then so sparse that no one realized that the expected glaciation had come and gone, cold but abbreviated and unrecognized.

I make 2 unpopular claims in that sentence: that a glaciation began; and that we stopped it. Granted, my hypothesis may be as unsatisfactory as all the others, but there is nothing to indicate that the driver of successful cycles has gone away.

At the time, no one believed that mere humans could affect an ice age. All that differed about the Final Vostok Glaciation was that item 3 of §2.1.1 was shortened by 2 orders of magnitude. Instead of 100,000 years of falling temperature, we got 1000 — but I admit to being more persuaded by logical necessity than by available data. If the LIA was not the initiation of the last Vostok glaciation, 1978's question returns. Where *did* it go?

Michael Mann has a short paper (2002) which is all but an epitaph for the LIA — and yet the first panel in his Fig. 2(a) shows exactly what I suggest is all that we will ever see of Vostok's Final Gasp (reproduced as Fig. 4 below). It is the Northern Hemisphere average of a suite of 7: West North America, Subtropical North Atlantic, Western Greenland, Central England, Fennoscandia, Eastern China, and Tropical Andes. These independently show the sort of random behavior described by Neukom — but together they become Fig. 4. If Mann had been arguing *for* the LIA, one might accuse him of selecting his data carefully, but he was arguing *against* the LIA being real, and still turned up what looks to me exactly like the first millennium of the average world-wide glaciation.

To be fair, Mann's "Central England" panel shows the Little Ice Age as a short cold spell following a pronounced Medieval Warm Period not evident elsewhere. Still, the average decline of 0.3°C/1000 years (the red line in Fig. 4) is the way a T-fall begins. A large part of the inability to identify the 900-1900 period as a coherent cooling was the localized North Atlantic Medieval Warm Period, which warmed central England and concealed the early cooling of the LIA. Historical records in the 15th century (Blom 2019) leave no doubt that people thought the cold was sudden and unexpected. For an impartial introduction to the LIA, see the bibliography at https://chaamjamal.wordpress.com/2018/07/19/liaclimatology, which has long paragraphs describing its 51 entries (few of which support my hypothesis, but do give some insight into the possibilities).

To make sense of the aborted-glaciation hypothesis we need to understand what drove the Vostok oscillation. The concensus is that planetary astrophysics offers the only cycles long enough to explain the 40,000 and 100,000 year periods in the Vostok data. The small changes which these produce in insolation at 65°N require positive feedback such as albedo decrease when lakes form on the ice sheet. Lee &3a (2017) suggest hemispheric differences in sea ice extent to explain the shift from 40-kyr to 100-kyr dominance, but Wunsch (2004) claims that Millankovitch can account for only 21% of the periodicity. I take this fraction to apply primarily to the start of a T-rise. Once it is in play, everything else follows automatically.

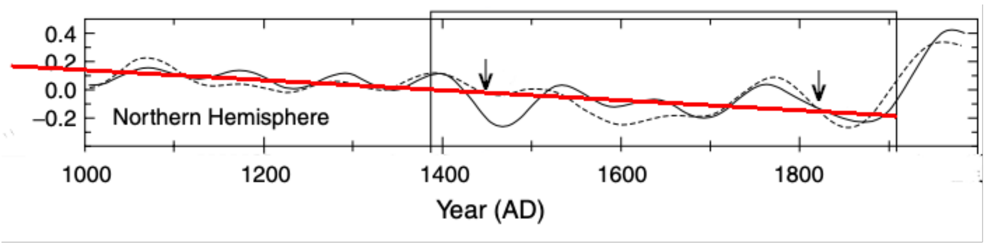

Fig. 4 The LIA as Glaciation. An 0.3°C fall in a millennium across the Northern Hemisphere looks a great deal like the first 1% of a 100,000-year glaciation. The initial cooling rate is higher than the 100,000-year average in every Vostok glaciation. The left arrow appears to be the elusive Kuwae eruption; the right arrow is the emphatic Tambora eruption, which seems to have delayed and sharpened the "hockey-stick" rise (see Fig. 3 for a more realistic view) The 1400-1900 box is a conventional version of the LIA (Hughes & Diaz 1994, Matthews & Brian 2005); my suggestion is the entire red line. (The graph is by Michael Mann (2002), who used it to argue against the 1400-1900 LIA-stub being taken literally) — although he also said "The 20th-century warming counters a millennial-scale cooling trend which is consistent with long-term astronomical forcing" In fact, if you look closely at (MBH 1999) Fig. 3(a), there is a "linear trend (1000-1850)" which is a perfect match to my eyeballed white line in Fig. 3 above.

This continuity is shown as a box in Fig. 4, following the putative Medieval Warm Period (MWP). With the MWP removed from the world data, T starts to fall at 900 CE, as in §2.1.1 item 3 above, and Figs. 3 and 4. This continues until 1884 (arbitrary, but the low point of NASA/GISS/GISTEMP v4 over-land) in the manner of a normal T-fall.

If Fig. 3 were cut off at end of the white line, it would be natural to expect the T-fall to continue at its millennial 0.3°C drop into a standard 100,000-year glaciation. This is twice the average 100,000-year rate, but this is normal in the early years when forests are removing CO_2 quickly as they expanding into bare land.

4.3 The Hockey Stick

The red "blade" in Fig. 3 was 25 years shorter when this graph was published, so it was dubbed "the Hockey Stick", violently attacked as bad science by the far right and described in *The Atlantic* as "the most controversial graph in science" (Mooney 2015). In fact it represents thousands of hours of work by hundreds of international scientists, often in the field under uncomfortable conditions. Its recognition ranks high on the list of scientific discoveries. Our response will define our future.

[Note for deniers: In the 4-billion-year perspective of the scientists who worked on this graph, it is thought of as "a review of current events" This is why so many predictions (sea-level rise, food crises, mass deaths by heat stroke, etc.) has ve not make headlines. Yet. As I edit the final draft of this paper (in early May, not even summer) the news talks of "night temperature 40.6°C" and "61 deaths by heat stroke in Thailand". A professor shows up in a side panel to point out that this is problem for city planners, etc, — and *deja vu*: I think,"That was why I didn't get excited about CO_2 in 1965 when I saw the infant Keeling curve: it was not a problem for a physical chemist; it was a problem for city planners and Congress ...."
No one expects either tolerance or scientific comprehension from the far-right, but please: Try not to chafe. *Be patient! And get out of the way!* Survival should be our full-time occupation for the next 30 years, because "The latest climate model scenarios show that all pathways that keep temperature rise to 1.5 degrees C (with little or no overshoot) require carbon removal" (AR6 SPM), and that is not easy. The longer we postpone corrective action, the harder it becomes to make the correction.]

Global warming and glaciations may be earth-shaking phenomena with extinction-level repercussions, but it seems that they may result from apparently trivial changes in a prosaic if seemingly ephemeral driver. A realistic round-number length of the LIA might be "900-1900 CE for The Final (Aborted) Vostok Glaciation".

5 The Troposphere

There are only 3 simple things needed to understand global warming These are:

1. the Lapse Rate
2. Adiabatic Compression
3. the Earth's Radiation Surface (ERS)

5.1 The Lapse Rate

There are 3 ways of thinking about the lapse rate. Daidzic (2019) offers half a dozen equations for calculating $(\delta T/\delta z)$, the rate of change of temperature with altitude. The StAt uses -6.5°C/km. The world's Weather Bureaus release 1800 instrumented weather balloons daily to measure the lapse rate up to 35 km in aid of predicting tomorrow's weather. The StAt's version is the red line through the troposphere in Fig. 5. The lapse rate runs through 90% of the mass of the atmosphere in the 10-mile troposphere thickness, and it is the site of all our weather. And that is really all one needs to know.

5.2 Adiabatic Compression

The invention of butyl rubber during WW2 killed the tire pump. This is unfortunate, because if you had to pump up a tire, the pump got hot, and you learned by experience that Adiabatic Compression is Always Warming. [There are 20 YouTube videos on "adiabatic compression", all specifically addressed to physical chemistry students. To my surprise, Wikipedia is deeply confused on this topic.] The only useful example I found was "Adiabatic cooling is the usual cause of clouds", equivalent to "adiabatic expansion is always cooling". Otherwise the available examples seem to be diesel engines running without spark plugs, because the maximum compression is hot enough to ignite the fuel. And there are downslope Santa Ana winds in greater Los Angeles and Chinooks east of the Rocky Mountains which are heated by adiabatic compression as they descend, with no external energy source.

No additional energy is needed for global warming. The energy comes from the sun and warms the ground.
With no CO_2 (or H_2O) in the atmosphere the ground could radiate it directly to outer space, and sealevel temperature would be the SB temperature, 255 K, -18°C, -1°F. (You could still fry eggs on desert rocks in the noon-day sun, especially below sea level. Choose a smooth, flat, dark, basalt rock: bits of weathered granite tend to stick to the egg.)
With CO_2 the Earth can radiate its 85% only in a random walk of 10-m steps, before being absorbed by another CO_2 molecule for a second, and then re-radiated in a random direction. The same process in the sun means that it can take a million years for energy to work its way out of the reaction shell to the surface where it can radiate away. The random walk only works because there are more molecules radiating upward in the denser lower layer. Upward paths into lower density are slightly longer than downward paths.

Radiative cooling is how one made ice for the Rajah's sherbet: no matter how hot the Indian day, if the air was dry, a thin layer of water in a flat pan would freeze at night because 15% of the radiation could make it out to the depths of space through gaps in the IR absorption of water vapor and CO_2.

Regional departures from the lapse rate create weather. Once the red line of Fig. 5 is understood, global warming is seen to be both a categorical fact like "snow lives on mountain tops" and a definitional fact like "water is wet" — and foolish to argue about.

5.3 The Earth's Radiation Surface

If astrophysics demands that the radiation temperature of the Earth be 255 K, and observed sea-level temperature is 288 K, it follows that the ERS lies somewhere along the lapse-rate line of Fig. 5. If you have a radiation physicist handy, the "somewhere" can no doubt be calculated, but for reasons that escape me, Goody's (1964) definitive treatment of radiation physics does not mention the concept, and the most promising item I found on the web, "The earth's radiation surface explanation pdf", turned out to be an irrelevant 50-page treatment of the solar spectrum under various conditions (Wald 2018).

Eschewing, then, scientific rigor in favor of working convenience, the "where" of the ERS can formally be found from the temperature difference between ground and -18°C, which we take as 33°C in 1880. This put the ERS at $z = (33C)/(6.5C/km) = 5,077$ m, about halfway to the tropopause. This is actually the center of a fuzzy band centered at the -18°C altitude, and there is nothing to see at that point.

Since we had a 15°C atmosphere, we have added some 140 ppm of CO_2 to it and the ground temperature has risen 2°C. from which we deduce that the ERS has risen to $z = 35/6.5 = 5,385$ m.

The ERS is didactic tool rather than a useful parameter. It is not something one would set out to measure as a way of tracking global warming. This is because radiation physics is one of the more complex disciplines, yet it tells us nothing new. The ERS will continue to rise as long as we put CO_2 into the atmosphere, and the ground temperature will rise along with it. Venus is the cautionary example. With a dense atmosphere of 96.5% CO_2, reflective clouds of SO_2, an SB temperature of 220°K but a ground temperature of 730°K (457°C, 854°F), it has a global warming of 510°C (Wood &15a 2022). I doubt that our fossil-carbon reserves are adequate to take us that far.

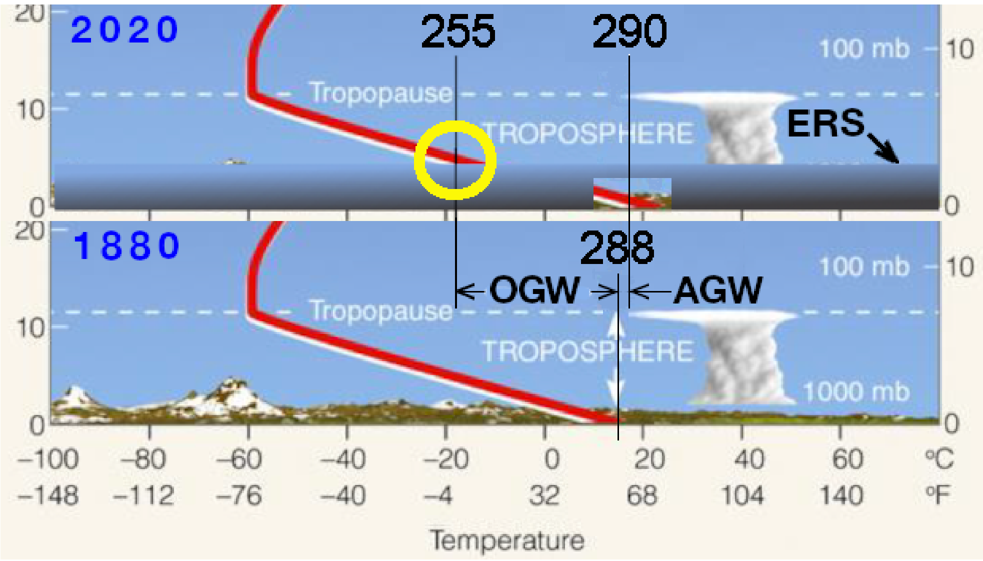

Fig. 5 Lapse Rate. The 1880 panel is the classical lapse rate from the *Standard Atmosphere*, anchored to the ground at the average 15°C or 288K, and it cools at an average of 6.5°C/km as it rises. **The 2020 panel's** anchor is the yellow circle at 255K, defining the Earth's Radiation Surface (ERS) In 1880 both anchors would have defined the same line. CO_2 below the ERS is shown as opaque in the IR. Altitude in km on the left, in miles on the right.

Figure 5 shows that there was no awareness of the ERS in 1880. The lapse-rate line was still arbitrarily anchored to the ground at 15°C (288 K) in 1956. If you are familiar with "Trenberth" diagrams — the complex IPCC images full of arrows depicting energy bouncing around in the atmosphere — the arrows that run from ground to mid-troposphere and then just stop without a visible or named destination represent energy that has arrived at the ERS the hard way and can now depart for outer space peacefully.

You'd think that there would be something detectable about the ERS. After all, as you cross it, the atmosphere loses 85% of the energy that it receives from the sun. But the ERS is still a kilometer above the mountain tops.

In the 140 years between the 2 snapshots, we added enough CO_2 to warm the land surface by 2°C. This puts the ERS at 35/6.5=5,385 m, for a rise of 308 m or 2.2m/year. The lapse-rate line is lifted bodily, maintaining its slope, and this moves the intersection with the ground 2° to the right, as indicated by the 290 K line and the window in the CO_2 "smog" in the 2020 panel.

Perhaps not obvious from the discussion or the arithmetic, the line connecting 33°C of OGW and 2°C of AGW in the 1880 panel shows that they are an arbitrary division of the same process, removing all speculation about what might be causing AGW.

Because we have added CO_2 so rapidly, the system is not in steady state as it was during the slow natural cycle. All of our climate-related anxiety is focussed on energy moving from the solar-heated ground to the ERS. The relation between added CO_2 and temperature rise is not in balance. The air over the ground, on average, is now a degree warmer than the air over the ocean. If we stop adding CO_2 today, the temperature will continue to rise — but here we reach the limits of the 80% approach. Until we understand where the missing MI goes, we are not in a position to estimate future temperatures. It is indicative, however, that during the natural Vostok cycle, there were 10°C changes for 30 ppm of CO_2 change over the 100,000-year cycle. How much of this 10° is positive feedback (albedo, circulation patterns, thermal lag) is anybody's guess, given the current state of computer models.

5.4 Radiation Physics

Radiation physics gets us into quantum-mechanical processes which have been exploited by deniers to confuse the issue. The free atmosphere and the spectrophotometer tube are different environments with different quantum-mechanical regimes. In spectroscope tubes at low concentration, an intercepting molecule ls detected by scattering beam energy into the tube wall. In the atmosphere, that energy is not lost, just moved sideways. At high concentrations, "stimulated emission" (Einstein 1916) encourages a CO_2

molecule to emit radiation instead of absorbing it, giving rise to "saturation" and the belief that adding more CO_2 to the atmosphere leads to a logarithmic response instead of linear (Schildknecht 2020). The author clearly knows his subject, making his misrepresentation appear deliberate disinformation. In any case, the free atmosphere always has unsaturated CO_2 molecules above the ERS, so the paper is not relevant to global warming.

In 1880, 290 ppm of CO_2 got us 33°C of OGW. Another 140 ppm of CO_2 has only added 2°C of AGW. so either the time required to reach steady-state is long compared to 150 years, or we've all overlooked something, or both. In this quandary there is little point in trying to estimate the elusive "climate sensitivity" (the temperature response to doubling CO_2) There was a time when this was a single number, ranging from 0.5°C to 9°C, by 1979 it was between 1.5°C and 4.5°C. "We remain unable to rule out that the sensitivity could be above 4.5°C", say (Sherwood &24a (2019) in a 92-page article. Today it is a world map with contour lines. While the problem is capable of keeping large computers happily employed, there always seems to be a sentence tucked away in the Results: "notable features of the geographical temperature response [are that] response patterns generally do not resemble the forcing patterns", showing that there is more to be learned.

Vince (2024) has a *Guardian* article describing the world of 2100 awaiting our grandchildren if we don't return the atmosphere to 310±10 ppm of CO_2, and it seems clear that she arrives at her optimistic description by overestimating both political cooperation and technological capability.

6 Adaptation

A favorite talking point of deniers is that alarmists overlook the ability of nature to adapt to changes (Lawson 2008). After all, climate has been changing for 4 billion years, and life survived.

This sounds plausible but overlooks 2 facts. The rate of change today is 100 times the natural rate, putting more stress on adaptation than it can cope with. Also, the first step in adaptation is generally for the unadapted to die off, allowing the few with protective mutations to prosper — and yes, that is happening to other species, and it will happen to ours too. Evolution does not look ahead: politicians (Lawson is a member of the British House of Lords) seem to have the same difficulty. Granted, Lawson was no doubt thinking of social adaptation, not evolutionary, but even so, we have known what was coming for half a century with no sign of adapting.

One thing that will be wanted even in Vince's optimistic world is better, deeper soil, both for food production on a smaller habitable land area, and for sequestering CO_2.

6.1 Sequestering CO_2

Most discussions of sequestering CO_2 involve capture at source, piping to a suitable geological formation, and pumping it back underground at high pressure. This is expensive in terms of energy, infrastructure, rights of way, maintenance, and if exhausted oil wells are any guide, it will leak.

Marine storage of CO_2 is difficult to estimate and impermanent. Keeling (1965) found that 47% of anthropogenic production goes into the ocean as long as we add CO_2 to the atmosphere. MacIntyre (1980) thought 40%. Watson (&9a 2020) suggested 25%. In any case, the ocean will re-equilibrate with the atmosphere as we remove CO_2, compounding the difficulty of sequestration.

For industrial situations in which CO_2 is available at reasonable concentration, it can be used as a feedstock for plastic manufacture (Gruter 2023). It is not clear that this is relevant to CO_2 already in the atmosphere. Perhaps more promising is co-pyrolysis of biomass and plastic waste together, simultaneously producing biochar, bio-oil, and bio-gas (according to the optimistic authors) (Chiun &6a 2023).

The target is to return the atmosphere to 310±10 ppm of CO_2 (Hansen &9a 2008). It is now 425 ppm, so this means removing and sequestering 115 ppm. (1 ppm of CO_2 weighs 2.13 GT.) The only practical energy source for this (comparable to what we have used during the Industrial Revolution, WW2, and everything since) is sunshine, photosynthesis, and time, and one logical approach is tallgrass.

While most writers see switchgrass (*Panicum virgatum*) as a suitable crop for marginal land (Hestrin 2020), I see it as a made-to-order tool for sequestering CO_2 in 40-foot deep soil (yet to be created). In what appears to be part of the ideal response, one grows a suitable member of the 200 varieties of perennial tallgrass, harvests it for char and carbon **monoxide** CO, impregnates the char with plant nutrients, puts it to work by making terra preta soil, and sells the CO as feedstock for a rebuilt plastics industry (Gruter 2023). Equally promising (according to the optimistic authors) is co-pyrolysis of biomass and plastic waste, simultaneously producing biochar, bio-oil, and bio-gas (Chiun &6a 2023).

"Terra preta" is the anthroposol invented by an exterminated people of the Amazon Basin. It is a chernozem/molllisol, 15% charcoal and often 2 meters deep, with artefacts at every depth (testifying to its artificial nature) It is mined and sold to the U.S. as potting soil. Current farmers claim that unlike other soils, it doesn't degrade with time, but this may be overly optimistic. Because switchgrass roots grow 40 feet deep, for maximum sequestration we want the soil that deep also. Every paper so far discusses soil depths up to 1 meter, but we have no problem creating machinery to handle 40-foot-deep soil building. One problem: while rice char is being used in Asia, for best results we want 3-dimensional char in 1-cm chunks, with maximal internal surface area for nutrient chelation. This is the key to permanent (nutrient-recycling) soil structure.

Initially, terra preta seemed ideal for California's Central Valley and the prairies (Purakastha &3a 2008) above the Ogallala Aquifer (South Dakota to Oklahoma panhandle), but it might be prudent to reform the Canadian prairie first, in case the southern area becomes too warm too soon.

Soil-deepening will probably be a bootstrap process, beginning with 1-m soil on broad areas, then gradually deepening them. The availability of precipitation will no doubt guide this work. Irrigation in the Ogallala is currently lowering the water table.

We know how to do this sort of adaptation, starting tomorrow. It may not solve the problem, but it will help.

6.1.1 Black Soldier Fly

As usable soil area shrinks, red-meat production at 2-4 steers/acre becomes far too inefficient to survive as a primary food source. Insect protein is considerably more efficient, and my cats — fastidious eaters — approve whole heartedly of unprocessed *Hermetia illucens* larvae. These are 25 x 6 mm diameter (1" by 3/16") consumers of organic waste, 500 eggs per batch, 3 generations per year in the wilds of the U.S. South, "self-harvesting" after 14-day development (Newton &4a 2005). The question is one of adaptation: how much processing would it take to convert insect protein into something the red-meat contingent could swallow?

Other adaptations will be net benefits whenever we manage to do them. They have been the target of continuous research for decades, so even if relatively little known, they have long had active advocates. Vince's (2019) map suggests that Edinburgh, Scandinavia, and St. Petersburg will survive as academic centers, so we should probably ensure that they are well prepared.

As the uninhabitable equatorial zone enlarges, we leave uranium reactors behind. Thorium-burning molten-salt nuclear reactors are a safe form of nuclear energy (see Wikipedia).

The permafrost of Siberia will thaw, opening pristine mud to mineral prospecting and Sinorussian conflict. If we think that cooperation in the face of extinction-level threat will make nuclear weapons obsolete, we can move to thorium. (On the other hand, if we think that nuclear weapons are the solution to territorial claims in the northern habitable zone, perhaps none of this matters, but we might be able to restart from a New Zealand base?) The world might find it useful if Auckland and Otago had reserve copies of all the knowledge that we think worth preserving. Just in case. According to recent Nvidia videos, "Grace Hopper" systems are, or soon will be, up to the task of storing a unversity library's worth of books — and explaining them to us.

6.2 The 80% Model

With its focus on the obvious, the 80% Model of Table 3 can help one ignore disinformative web pages that argue about the emissivity of the earth and the grayness of its blackbody, the variation of its albedo and the shape of IR absorption lines, the depth of the carbonate compensation level in the Atlantic and the disintegration of polar ice shelves, the ozone hole and UV reactions in the stratosphere, the AMOC and the PDO, cosmic rays and cloud nuclei, the size distribution of cloud droplets, the slow growth of the sun's core, and many other details that are available for argument. These are mostly real, interesting and sometimes important, but their influence on the rate of temperature increase is negligible. The basic idea of the 80% Model has long been well known, it agrees with international climate labs, introduces no errors, and any 6th grader who has been to the Dead Sea, Death Valley, or even the Coachella Valley Music and Arts Festival (all below sea level and hot) will understand it experientially.

[Table 3 near here.]

The single most important aspect of Fig. 5 is that there is nothing to stop the ERS from rising at least to the tropopause unless we run out of fossil carbon. I think the 80% Model stops working at the tropopause, but if we got that high the ground temperature would be $(116.5) - 18 = 53.5$°C, 327K or 128°F. As Pierrehumbert (2011) says: "Hot as Venus is, it would become still hotter if one added CO_2 to its atmosphere".

The LIA, it seems to me, was doing its best to become a real glaciation, but we thwarted it, evidently by burning British coal at the beginning of the Industrial Revolution. The T-rise that ended the previous glaciation restarted in 1884 right where it left off 12,000 years earlier. It will not stop rising until the surface ocean warms to steady state with the lower atmosphere some time (decades?) after we stop adding CO_2 to the system.

Stopping a glaciation seems like a heroic act, considering that a full-fledged glaciation puts a 3-km layer of ice on Canada. Apparently, it is straightforward if done right. Perhaps all one needed was to put CO_2 into the air faster than the Northern Hemisphere's forests could remove it. We managed that early in the Industrial Revolution (and the thawing of clathrates during a T-rise has the same effect) If that seems unlikely, recall that early steam engines were about 3% efficient and burned 15 times as much coal as current devices.

And now that we have successfully stopped the glaciation:

"The enormity of consequences demands a return to Holocene-level global temperature" (Hansen &16a 2023) — which to me implies Holocene CO_2 levels. Anyone remember Goethe's poem *Der Zauberlehrling* (1797) (The Sorcerer's Apprentice)? (Or Mickey Mouse in *Fantasia* (1940), with the broom and buckets?)
The positive implication is that after we return to 310±10 ppm, we could safely emit 1.5 ppb annually. At 1PPM CO2= 2.12 GT Carbon (IPCC), that would be 15 ppb CO2= 31.8 MT Carbon, or abut 6% of current annual U.S. coal production.

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Table 3 THE **80% MODEL** OF GOBAL WARMING

OBSERVATION (some are facts)	**COMMENT** (here too)
•Heat is energy in motion. In the air it is a random walk of 10 m as infrared (IR) radiation and 1-second stops as a molecular excitation, •**Stefan-Bolzmann physics** says Earth receives 5800K energy from the sun and reradiates it to space as IR at 255°K (–18°C, 0°F). •$\Delta T = 288 - 255 = 33$°C is **Ordinary Global Warming (OGW)**, always with us but seldom noticed. •A 0°F sun-warmed Earth would be a chilly place, so something else is going on! **IR cannot warm N_2 and O_2.**	•and a billion impacts with other air molecules to establish local equilibrium before reradiation, downward half the time. •The Weather Bureau and *U.S. Standard Atmosphere* put the Earth's average ground temperature at a pleasant 288°K (15°C, 60°F). •$\sim$ 2°C of **Anthropogenic Global Warming (AGW)** is more of the same process, a recent addition, but politically denied. •The "something else" of OGW is molecules with 3 or more atoms: CO_2, H_2O, &c. which intercept IR and change its direction.
•Most H_2O vapor is removed by condensation at the dew point (cloud base), $\sim$ 1500 m. •15% of outgoing radiation comes from the ground. 85% is from the **Earth's Radiation Surface (ERS).** •No additional heat is needed for O/AGW. It is merely solar heat having a hard time leaving. It made Earth life possible for 3 billion years. •CO_2 density low enough for 50% of the IR to escape sets the -18°C level. Ground heat works its way up by convection and the random radiation walk. •The *US Std Atm* defines a mean-humidity **lapse rate** ($\delta T/\delta z$) — temperature change with altitude — to be **–6.5°C/km** •The height of the –18°C level of the lapse rate is set by CO_2, and its height determines ground temperature.	•This leaves CO_2 as "the control knob of climate" for the next 3,500 m. •The 15°C ground surface cannot be the ERS. Watch the video at: **https://svs.gsfc.nasa.gov/5110 .** •Increasing pressure below the ERS raises internal energy. **Adiabatic compression is always heating.** •When it isn't 10-m radiation steps, it is molecular velocity, whose temperature is that of adiabatic compression, decreasing linearly as it rises. •300 ppm put the Earth's Radiation Surface at 33°C/(6.5°C/km) = **5,077 m**, half way to the tropopause, without visible structure. •425 ppm put the ERS at 35/6.5= **5,385 m** This is the mean of a fuzzy gradient, which can rise at least to the tropopause.
•Carboniferous bacteria could not eat wood, which got buried and converted to coal and oil 300 million years ago. Was this Providence ensuring that the Holocene "Garden of Eden" would be available when we were? •Or was it fortuitous fine tuning which granted us a comfortable Holocene? Abrahamic religions credit it to a benevolent deity. •This matters because there is no effective limit to AGW. Our 424 ppm is 141% of Vostok's 300 ppm, which might get us to 141% of the 33° of OGW in decades. Or centuries. •Climatologists suggest that 4°C of AGW will make 90% of the land uninhabitable. People die en masse when the wet-bulb temperature of the humid tropics exceeds body temperature. •The 100,000-year T-Fall might be biochemical, with 1.5 ppb of CO_2 as decay-resistant litter each autumn waiting for the next T-rise. •The Vostok cores tell us much about a 300-ppm world — but very little about a 425-ppm world. We are in terra incognita, full of surprises, none pleasant.	•(Fungi eat wood today.) We dug up and burned the coal and oil for energy to build a civilization before recognizing it as a **poisoned gift** And we dumped the CO_2 back in the atmosphere without a 2nd thought. •**Adiabatic compression is always warming.** Cf. diesel engines, tire pumps, and downslope winds (Chinook, Foehn, Santa Ana). •The final Vostok glaciation — 900 CE to 1900 (the Little Ice Age) — was dramatically reversed by early Industrial CO_2 (Mann's Hockey Stick). •141% of OGW's 33°C would add 46°C to the -18°C sunshine, for 13°C of AGW and a ground temperature of 28°C or 82°F — if we stopped adding CO_2 today. •T-rises are triggered when Milankovitch sun thaws Arctic methane clathrates. Humus decays during 10,000-year T rises. •On Venus, SB says 220K, but a 96% CO_2 atmosphere gets 510°K of OGW and a red-hot surface at 730°K, 460°C, 850°F. Same process as ours, just more CO_2.