GLOBAL WARMING IN THE PIPELINE: HANSEN, SATO, SIMONS, et al. 2022 (LINK)

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"OUR PRINCIPAL MOTIVATION IN THIS PAPER..."

• "...is concern that IPCC has <u>underestimated</u> climate sensitivity and <u>understated</u> the threat of large sea level rise and shutdown of ocean overturning circulations." - Hansen et al.

Global warming in the pipeline

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ABSTRACT

Improved knowledge of glacial-to-interglacial global temperature change implies that fastfeedback equilibrium climate sensitivity (ECS) is 1.2 ± 0.3 °C (2 σ) per W/m². Consistent analysis of temperature over the full Cenozoic era – including "slow" feedbacks by ice sheets and trace gases – supports this ECS and implies that CO₂ was about 300 ppm in the Pliocene and 400 ppm at transition to a nearly ice-free planet, thus exposing unrealistic lethargy of ice sheet models. Equilibrium global warming including slow feedbacks for today's human-made greenhouse gas (GHG) climate forcing (4.1 W/m²) is 10°C, reduced to 8°C by today's aerosols. Decline of aerosol emissions since 2010 should increase the 1970-2010 global warming rate of 0.18°C per decade to a post-2010 rate of at least 0.27°C per decade. Under the current geopolitical approach to GHG emissions, global warming will likely pierce the 1.5°C ceiling in the 2020s and 2°C before 2050. Impacts on people and nature will accelerate as global warming pumps up hydrologic extremes. The enormity of consequences demands a return to Holocene-level global temperature. Required actions include: 1) a global increasing price on GHG emissions, 2) East-West cooperation in a way that accommodates developing world needs, and 3) intervention with Earth's radiation imbalance to phase down today's massive human-made "geo-transformation" of Earth's climate. These changes will not happen with the current geopolitical approach, but current political crises present an opportunity for reset, especially if young people can grasp their situation.

A KEY CONCLUSION: "EQUILIBRIUM GLOBAL WARMING (ESS) INCLUDING SLOW FEEDBACKS IS +10C (FOR TODAY'S OBSERVED CLIMATE FORCING)"

ANTHRO AEROSOLS HAVE REDUCED **ESS** TO +8C (BUT WE'RE SCRUBBING THEM OUT)

DEFINITION: ECS vs. ESS

- ECS = "Equilibrium Climate Sensitivity" (to a doubling of CO2 concentration) but with only the fast climate feedbacks: meaning keep "ice sheets, vegetation and other long-lived GHGs fixed (except the specified CO2 doubling)".
- ESS = "Earth System Sensitivity" (includes the slow feedbacks too; large ice sheet changes, full ocean turnover, large scale changes to the biosphere, all GHG changes).
- <u>ESS is approximately 2x ECS</u>... says paleo and climate models. If we are concerned with the long term safety of Earth, it is ESS that should most concern us. But ECS is more prevalent in the literature, which concerns the short term; addressable with very recent observable data of presumably higher reliability.

THE ENTIRE 62 PAGE HANSEN STUDY BRINGS IN FAR TOO MANY LINES OF EVIDENCE EVEN TO SUMMARIZE HERE, EXCEPT FOR THE MOST IMPORTANT POINTS

- But they support the conclusion that ECS and ESS are significantly higher than conventional climate models have found. Separate lines of evidence for ECS and also for ESS, mutually reinforce.
- They bring in Pliocene data (when CO2 only 300 ppm, yet as warm as today; climate models unable to reconcile this w/o higher ESS.
- Full Cenozoic period data, which support 1.2 W/C forcing to agree with O₁₈/O₁₆ temperature history, which corresponds to an ECS ~+5C; higher than conventional climate models...
- ...and far more.

THE INFLUENTIAL CHARNEY REPORT OF 1979, DEFINING ECS AND CLIMATE CHANGE... HAD A MAJOR ERROR:

- "The (Charney) report <u>assumed that the delay of global warming caused by</u> the ocean's thermal inertia is only 15 years, independent of climate <u>sensitivity</u>.
- *"With that assumption, they concluded that climate sensitivity ECS for 2×CO2 is near or below the low end of Charney's ECS=1.5-4.5°C range.*
- "If climate sensitivity was low and the lag between emissions and climate response was only 15 years, climate change would not be nearly the threat that it is." – Hansen et al. 2022
- Note 1979: This was BEFORE climate change really kicked in, since aerosol masking was very effective in counteracting CO2 rise until the 1970 Clean Air Act took effect - unappreciated in Charney's day.

SO... HOW TO EVALUATE <u>ESS</u>? HANSEN USES PALEO DATA AT TIMES WHEN CLIMATE FORCING IS ZERO: AT GLACIAL MAX, AND THEN AT WARM INTERGLACIAL STABILITY POINTS

- Earth was in ~equilibrium at the LGM (Last Glacial Maximum 20kya).
- And, Earth was in ~equilibrium in the <u>early</u> Holocene. Not so today; Humans have affected climate as far back as the dawn of civilization, through deforestation and rice cultivation (Ruddiman), and radically even larger forcing is in effect today.
- Hansen uses 7,000 years ago as Holocene's equilibrium time for T and CO2 benchmarks.

WHAT WAS GLOBAL AVG TEMPERATURE DROP RELATIVE TO HOLOCENE, AT LAST GLACIAL MAXIMUM (LGM)?

- Older studies mistakenly used micro-fossil species distributions as a temperature proxy.
- But the evolutionary adaptation time scale goes inverse to individual species member's lifetimes, and so is short compared to the ~30,000 yr time scales of climate change. So, the argument has shifted, and LGM temperature drop was more severe than the milder latitude shifting of species distributions would suggest, because of this evolutionary adaptation.
- Therefore, did not use micro-fossils to find the temperature at the LGM.
- Instead, use geochemical-based T proxies...



CLIMAP(1981) AND LATER MARGO DATA CAN BE RULED OUT; GIVE FAR TOO WARM AN ESTIMATE OF LGM TEMPERATURE

- "A warm LGM suggested by CLIMAP and MARGO49 data (only ~3°C cooler than the Holocene) can be firmly rejected, because it is now certain that their SST (sea surface temperature) data yield a planet out of energy balance by more than 2 W/m², as discussed above.
- An energy imbalance of +2 W/m² is enough to raise the temperature of the upper kilometer of the ocean 2.2°C or melt ice to raise sea level 22 m in a century and 10 times those amounts (220 m) in a millennium. <u>Such change rates did not occur.</u>" (Hansen et al. p. 11)

SO; WARM LGM ESTIMATES NOT FAVORED... THEN WHAT IS THE NEWER LGM TEMPERATURE ESTIMATE?

- Selzer *et al.* (2021) use noble gases solubility to find mid/low-latitude lands cooled <u>5.8C</u> at LGM *vs.* Holocene. Now add Arctic Amplification via ice sheet albedo effect, and get <u>7C</u> for <u>global</u> avg cooling at LGM.
- Tierney *et al. (2020),* in line with prior arguments, exclude microfossils dependence and use other T proxies to get <u>6.1C</u> for 23-19kya period, but this time was not well centered on equilibrium LGM, and Tierney suggests (personal comm. to Hansen) that <u>7C</u> is a better number.

Osman et al. (2021) similarly find T = 7C cooler, for 21-18kya period.

EVIDENCE POINTING TO HIGHER ECS THAN THE STANDARD IPCC ECS (OF 3C) DATE BACK MORE THAN A DECADE.

- A Quote From of Fasulo & Trenberth (2012) (<u>Digest here</u>)..."...while FS12 does not provide a specific measurement of climate sensitivity, it does suggest low sensitivity models are not accurately representing changes in cloud cover.
- Climate models with higher sensitivity in the 3 to 4.4°C ECS range for doubled CO2 - more accurately simulate the observational RH (relative humidity) data and thus the response of subtropical clouds to climate change." (Fasulo & Trenberth 2012)"
- (Other high ECS's, from Sherwood and others)

SIMILARLY, <u>STEINTHORSDOTTIR *et al.* 2020</u> FIND ECS MUST BE MUCH HIGHER THAN USUAL +3C IN CLIMATE MODELS...

- ... in order to explain the high temperatures of the Miocene epoch; +7C hotter than today yet at pCO2 of only <~500 ppm, not much above today's 425ppm, and, too, at lower solar radiation.
- "A problem remains that climate models cannot reproduce MCO(Miocene climate maximum) temperatures with less than ~800 ppm pCO₂, while most previously published proxies record [that] pCO₂ < 450 ppm"

HANSEN AND SATO 2012 FIND THAT AN <u>AVERAGE</u> ECS=3.0C (BLACK) FITS EARTH CLIMATE (RED) GOING INTO AND OUT OF ICE AGES FOR THE PAST ~MILLION YEARS, *i.e.* FOR CO2 RANGES FROM 170-280PPM. BUT, <u>THEY POINT OUT THIS ECS SHOULDN'T BE USED FOR PROJECTIONS IN OUR FUTURE</u> <u>SINCE WE ARE TODAY QUITE ABOVE THIS LOW CO2 RANGE. (AND; ECS IS NOT A CONSTANT; IT IS</u> <u>CLIMATE STATE / CO2 LEVEL DEPENDENT). AND IT'S AN AVERAGE OVER A VERY CHOPPY EPOCH.</u>



Figure 3: Black curve: calculated surface air temperature change for climate forcings HS12 and climate sensitivity 0.75°C per W/m2. Red curve: estimated global surface a temperature change based on deep ocean temperatures and assumption th LGM-Holocene surface temperature change is 4.5°C. Zero point is the 800 ky mear Figure 6 from HS12.



FRIEDRICH *et al.* 2016 FIG 3. FINDS ECS VARIES FROM +1.88C TO 4.88C IN/OUT OF GLACIALS. DOTS ARE PALEO DATA: A STRAIGHT SLANTING TREND EQUIV TO CONSTANT ECS.

THE STRONG UPWARD CURVATURE SAYS <u>HIGHER ECS</u> APPLIES AT HIGHER TEMPERATURES.

THE ORANGE LINEAR BAND ASSUMES **ECS=4.88C** HOLDS TODAY AND FOR THE FUTURE.

HOWEVER, THIS ORANGE FUTURE SLOPE LOOKS SHALLOWER (LOWER ECS) THAN THE ORANGE PALEO DOTS INDICATE – MEANING, AN ECS EVEN HIGHER IS QUITE POSSIBLE, SINCE ECS=4.9C WAS WHAT APPLIED DURING THE INTERGLACIALS OF THE PAST 2 MILLION YEARS, WHEN ATMOSPHERIC CO2 NEVER GOT ABOVE 280ppm – YET WE'RE AT 425 ppm NOW.

MICHAEL MANN'S JUDGEMENT? "THIS STUDY IS SOUND, AND QUITE DEFENSIBLE" (SOURCE) VON DER HEYDT *et al.* 2016 SUMMARIZING STUDIES SHOWING ECS DEPENDENCE ON UNDERLYING CLIMATE STATE. EVIDENCE IS STRONG THAT <u>ECS/ESS IS HIGHER IN HOTTER CLIMATE STATES, EVEN</u> WHEN EARTH IS ICE-FREE SO ICE ALBEDO ISN'T THE CAUSE (EOCENE

<u>e.g.).</u>

State dependent ECS from palaeoclimate data and models



GISS CLIMATE MODELLING: FAST FEEDBACKS MOSTLY REALIZED BY ~100 YRS. SLOW FEEDBACKS TAKE ~2,000 YRS TO REACH <u>ESS</u> T RISE. BUT NOTE <u>HIGHER ECS MEANS LONGER TIME TO EQUILIBRIUM</u>.



response function (percent of final change). Thick lines in Figs. 4 and 5 are smoothed⁷³ results.

EEI *vs.* TEMPERATURE TIME SCALES: THIS IS AMONG THE MOST ALARMING CONCLUSIONS OF THIS WORK...



- Note that for EEI, fast feedbacks adjustment takes only <u>~1 decade</u>. It is EEI which we can hope to affect through legal policy. But temperature is what governs climate effects, and it takes fully ~10x longer (<u>a century or</u> <u>more</u>) for temperature to adjust to EEI fast feedbacks and then transition to the slower rise to ESS.
- Meaning: Current temperature change is truly "in the pipeline" and will emerge, almost regardless of any realistic policy changes. Current policy is only making this situation even worse.

THIS EEI *vs* TEMPERATURE TIME SCALE DIFFERENCE...

- "...has practical implications. First, EEI defines the <u>rate</u> that heat is pumped into the ocean, so if EEI is reduced, ocean warming is slowed. Second, rapid EEI <u>decline implies that it is wrong to</u> <u>assume that global warming can be stopped by a reduction of</u> <u>climate forcing by the amount of EEI</u>. Instead, the required reduction of forcing is <u>larger</u> than EEI. (p. 15)
- "The difficulty in finding additional reduction in climate forcing of even a few tenths of a W/m² is substantial" (Hansen J, Sato M, Kharecha P et al. Young People's Burden: Requirement of Negative CO2 emissions. Earth Syst Dyn 2017;8:577-616)

AN ESS OF ~+10C GLOBAL AVG TEMPERATURE CHANGE FROM OBSERVED FORCING, IMPLIES AN ECS = ~4.5-6C

- "The LGM-Holocene climate change implies ECS = 3.3-5.1°C for 2×CO2"
- "Osman, Tierney et al. LGM cooling of 6.8°C for 23-19 ky BP yields ECS = 3.7-5.1°C." (p.13)
- Get similar, for the ECS of previous glacial-to-interglacial...
- "the Prior-to-the-Eemian Glacial Maximum to -Eemian Interglacial, is seen to have ECS ~ 4-6°C." (p.13)

CONTRARY STUDY: <u>WANG *et al.* 2021</u> ARGUE THE "WOLF PACK" IPCC AR6 CLIMATE MODELS (HIGH ECS~+5C) OVERESTIMATE HOW EFFECTIVE AEROSOLS ARE IN COOLING CLIMATE.

- To explain: Climate models can reproduce recent observed warming in two different ways: Mild (blue) ECS w mild aerosol/cloud cooling, or (red) High ECS w strong aerosol/cloud cooling
- How to decide? <u>Most aerosols are produced in</u> <u>the land-dominated northern hemisphere</u>, so use GISS climate modelling with red, then blue, assumptions and compare NH and SH, see which best agrees with observations.
- They find, the mild assumption (blue) a better fit.



THE HANSEN *et al.* 2022 "PIPELINE" AUTHORS ARE IN DISAGREEMENT WITH THIS CONCLUSION

- Hansen's paper came out in 2022, and does not reference Wang *et al.* (2021), unfortunately. It would be a good question to ask Hansen *et al.*, and Wang, on reconciling their different results.
- Other work unrelated to Hansen's is also in conflict with the Wang et al. 2021 conclusion
- In particular, the new 2015, and further strengthened 2020 maritime laws limiting SO2 emissions in North Atlantic shipping has provided a good test to resolve this controversy (see coming slides)

THE HIGH ECS ARGUED FROM CLOUD FEEDBACKS AND ESS DATA, IS ONLY CONSISTENT WITH OBSERVED WARMING IF AEROSOL COOLING (BLUE) IS STRONG (HANSEN FIG. 6 BELOW). SO, WHAT DIRECT EVIDENCE ARGUES FOR STRONG AEROSOL COOLING? ...



Fig. 6. Observed global mean surface temperature (black line) and expected warming from observed GHG changes with two alternative choices for ECS. The difference (blue area) is an estimate of the cooling effect of the (unmeasured) aerosol forcing. The temperature peak in the World War II era is in part an artifact of inhomogeneous ocean data during that period.⁵⁴

GHG (ANTARCTIC VOSTOK ICE CORE CO2) FORCING TO PRODUCE OBSERVED GLOBAL TEMPERATURES (VOSTOK Tx0.75 TO CORRECT FOR SOUTH POLAR AMPLIFICATION, TO AGREE WITH OBSERVED T_{global}) IMPLIES FORCING (GHG+AEROSOLS) IS <u>ABOVE</u> IPCC, AND...



Fig. 7. Global mean surface temperature (left scale) and climate forcings (right). Scale factor between temperature and forcings is 2.4° C per W/m² (see text). Antarctic (Vostok) temperature change based on water isotopes^{87,88} is multiplied by 0.75. Time scale is expanded post 1750. Modern temperature is NASA GISS analysis.^{89,90} Zero point for GHG forcing is the mean for 10-8 ky BP, a period expected to precede significant human effects. GHG + IPCC aerosol forcing is indistinguishable from IPCC¹³ all-anthropogenic forcing (Supporting Material).

- ...shows GHG forcing (green curve) is already, today, at 2xCO2_{pre-ind} = 4 W/m^{2.}
- Yet <u>actual</u> CO2=422ppm is only 1.5xCO2_{pre-ind}
- With such strong forcing (green), why is it still so cool (black)? ...

"WE CONCLUDE THAT THE GHG INCREASE SINCE 1750 ALREADY PRODUCES A CLIMATE FORCING EQUIVALENT TO THAT OF 2×CO2"

- "(Our formulae yield F_e ~ F_s = 4.08 W/m² for 2021 and 4.13 W/m² for 2022; IPCC AR6 has F_s = 4.14 W/m2 for 2021)." (p. 8)
- In other words, <u>the IPCC AR6 and Hansen are in</u> agreement on this forcing, yet...
- Yet we're not at 2xCO2_{pre-ind}, we're at only 1.5xCO2_{pre-ind}
- So, why are we not hotter today? Conclude: <u>ECS is higher</u> than 3C, and being masked by understated aerosol cooling from human-caused aerosols.

THE RISE IN EARTH'S ENERGY IMBALANCE (HEAT IN, MINUS HEAT RADIATED) IS DRAMATIC IN PAST DECADE; EEI IN 2023 WAS ~4x WHAT IT WAS JUST 15 YEARS AGO. A STRONG CASE IS MADE THE CULPRIT IS AEROSOL MASKING



 NASA CERES data, 2023 (not from Hansen's paper)

 Note that EEI defines the RATE, the SPEED, at which global temperature rises. A constant EEI drives a constant RATE of RISE of global temperature!

THEREFORE; ACCELERATED WARMING IS IN THE PIPELINE. CHINA CLEAN AIR EFFORTS, BEGUN IN 2010, ARE IMPLICATED AS A PRIME CAUSE, AS IS NEW SHIPPING SO₂ REGULATIONS



Fig. 19. Accelerated warming rate post-2010 (yellow area) if aerosol reductions approximately double the net (GHG + aerosol) climate forcing. Upper and lower edges of the yellow area are 0.36 and 0.27° C per decade warming rates.

RAPID RISE POST 2020, IN SST'S ALONG NH SHIPPING LATITUDES. MANN SAYS HE STILL SEES OCEAN HEAT CONTENT SINCE LATE 20TH CENTURY RISING ~LINEARLY AND NOT READY TO SIGN ON TO HANSEN'S ACCEL CONCLUSIONS... BUT SUCH <u>TOTAL</u> OCEAN HEAT CONTENT GOES VASTLY DEEPER THAN SOLAR-ACCESSED DEPTH, AND SO IS SLOWER TO RESPOND; SO I AGREE W/ HANSEN *et al.*





PRIOR TO 2015-2020'S SO₂ RESTRICTIONS, PDO INDEX AND ABSORBED SOLAR RADIATION IN NORTH PACIFIC FOLLOWED EACH OTHER WELL. NOW, DIVERGING RADICALLY AS <u>ASR</u> (=ORANGE <u>ABSORBED SOLAR RADIATION</u>) BREAKS FROM PDO OSCILLATIONS AND CLIMBS SECULARLY, STEEPLY. THIS, EVEN THOUGH THE PDO HAS BEEN IN A COOLING PHASE (BLUE)



SUMMARY STATEMENTS... 1ST - ESS IS ~10C

- "During the past 800,000 years, CO2 provided ~80% of GHG climate forcing, i.e., the total GHG forcing is 25% larger than the CO2 forcing. Thus, the climate sensitivity in which non-CO2 GHG feedbacks are allowed to change increases from ~4°C to <u>~5°C.</u>"
- (Interpretation; the rising PF methane and NOx emissions, and methane clathrates in shallow ocean sediments... are feedback'd as well)
- "When all feedbacks, including ice sheets, are allowed to respond to the climate forcing, the equilibrium response is approximately doubled, i.e., ESS is <u>~ 10°C</u>
- With all trace gases included, the increase of GHG effective forcing between 1750 and 2021 is 4.09 W/m2, which is equivalent to increasing the 1750 CO2 amount (278 ppm) to 561 ppm (formulae in Supporting Material). <u>We have already reached the GHG climate forcing level of doubled CO2.</u>

SUMMARY STATEMENTS: ECS AT PETM (55Mya)...

- "The Paleocene-Eocene Thermal Maximum (PETM) provides an opportunity to assess climate sensitivity in the absence of large ice sheets. PETM warming of about 5-6°C was driven by an approximate doubling of CO2, which occurred over a period of 3,000-10,000 years.
- If we assume that forcing by non-CO2 GHGs increased in the same proportion (~25%) to CO2 forcing as in the period covered by ice core data, we obtain an ECS estimate of 4-5°C for 2×CO2.
- High ECS in a warm ice-free climate may be a result of amplifying cloud feedbacks, and a rising tropopause may also contribute to high ECS in warm climates."
- (55Mya the continent positions were little changed from today).

RECALL FROM <u>NOLTHENIUS (2022 P. 19)</u> REFERENCE TO CARBON EMISSION FROM PEAT LANDS AT TODAY'S CLIMATE FORCING: HANSEN COMMENTS...

(p. 26) "Another potential feedback contribution, from peat, seems almost unavoidable. Northern peatlands today contain more than 1000 Gt carbon, much of which could be mobilized on millennial time scales at PETM warming levels. Numerous hyperthermal events in the Cenozoic record testify to the importance of such feedbacks, because the events seem to be spurred by modest orbital forcings and include negative carbon isotope excursions. Emissions from such feedbacks, including the terrestrial biosphere and permafrost, seem to be more chronic than catastrophic on the short-term, but if policies are not designed to terminate growth of these feedbacks (Section 6), it may become impossible to avoid climate catastrophe."

CENOZOIC CO2 AND CLIMATE HISTORIES REVEAL WHERE CLIMATE IS HEADED...

- "if present human-made climate forcings remain in place. GHG climate forcing is now 4.6 W/m2 relative to the mid-Holocene (7kyBP) or 4.1 W/m2 relative to 1750. We argue that 4.6 W/m² is the human-made forcing, but <u>there is little point to debate whether it</u> should be 4.6 W/m² or 4.1 W/m² because the GHG forcing is increasing 0.5 W/m² per <u>decade</u> (Section 6.7).
- "One merit of consistent analysis for the full Cenozoic era is revelation that the <u>human-made climate forcing exceeds the forcing at transition from a largely ice-free planet to glaciated Antarctica</u>, even with inclusion of a large, negative, aerosol climate forcing. Equilibrium global warming for today's GHG level is 10°C for our central estimate ECS = 1.2°C ± 0.2°C per W/m² (equiv to ECS=+5C), including the amplifications from disappearing ice sheets and non-CO2 GHGs (Sec. 4.4). (Anthro generated) Aerosols reduce equilibrium warming to about 8°C. Equilibrium sea level change is +60 m (about 200 feet)."

FINALLY: (NOT HANSEN) GROWING EVIDENCE THAT ATMOSPHERIC CO2 CONCENTRATION IS NOW RISING SIGNIFICANTLY FASTER THAN <u>DIRECT</u> HUMAN CO2 EMISSIONS. ARE INDIRECT ANTHRO EMISSIONS TAKING OVER, AND AS NORMAL LAND/OCEAN CAPTURE DROPS?



1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO₂) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO₂ includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

A record annual increase in the amount of atmospheric CO₂

Monthly year-over-year change measured in parts per million at the Mauna Loa observatory

NO HINT OF A PAUSE IN EXPONENTIAL ATMOSPHERIC CO2 RISE, EVEN WITH THE COVID RECESSION AND SHALLOWING EMISSIONS RATES. TODAY=425 PPM

Supplementary Figure 2 Comparison of global net land CO₂ fluxes between the 3 DGVMs used in this study (black dots for NRT version, a red dot for NRT version in 2023, gray squares for TRENDY version) and the distribution of 21 TRENDY models (green bars, with color intensity representing the number of DGVMs falling into each interval) used in latest Global Carbon Budget edition[7]. Note that the 3 DGVMs have been biased corrected to have the same net land sink than the average of TRENDY models during 2019-2022, but their anomalies are feely calculated for all years including in 2023.

ALIGNS WITH KE et al. 2024 – JUST POSTED LAST WEEK... SHOWING NET LAND CAPTURE OF CO2 DROPS TO ZERO IN 2023

THANK YOU, UCSC FACULTY, FOR YOUR INTEREST ON THIS DAY JULY 23, 2024.

THIS, THE HOTTEST GLOBAL TEMPERATURE DAY IN AT LEAST 100,000 YEARS

SOME LAST SECOND ADDITIONS...

- How much total summed \$ investment in CO2 removal research and development since 2009? <u>\$3 billion.</u>
- ...Far less than the real estate value of a single square mile of our little beach town of Santa Cruz.
- 3 page summary of this Hansen paper is here, and full paper is here