Global Temperature Increase Expectations

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January 12, 2020; Revised Jan 15, 2021

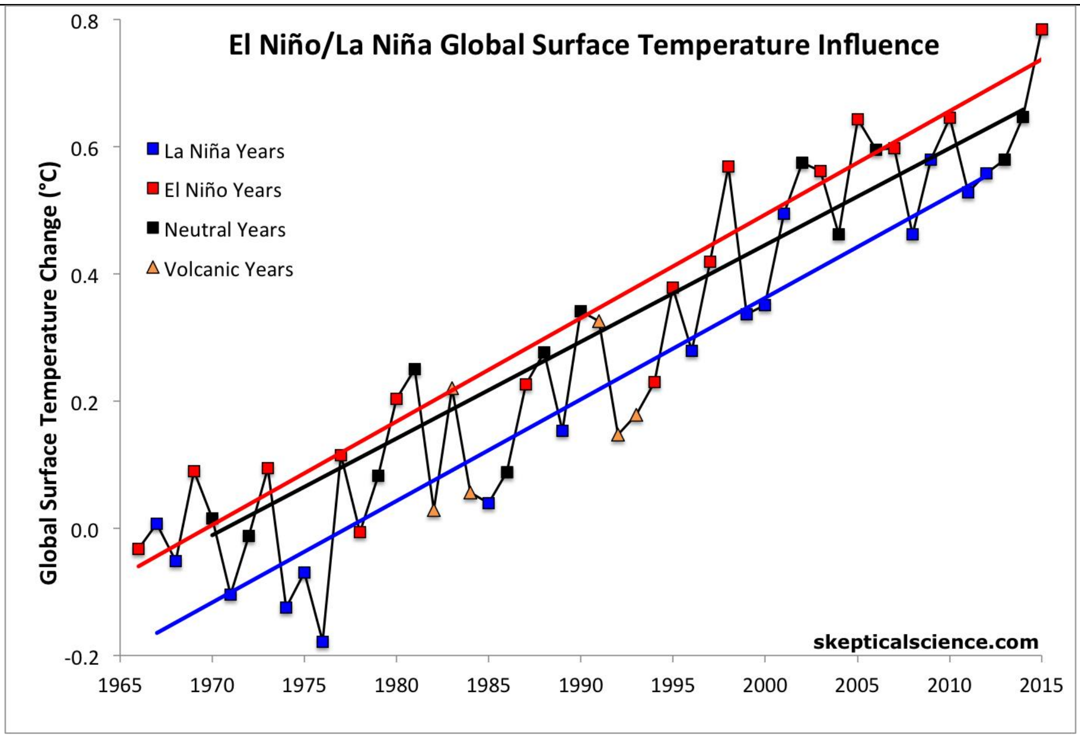
http://ccdatacenter.org/documents/TempIncreaseExpectations.pdf

- The global average temperature has been increasing at about 0.18°C per decade since about 1970, and the annual temperature is significantly affected by the El Nino/La Nina oscillation[1,19]
- Although the years 2015-2019 were significantly above the average of the preceding 10 years[2,19], they are pretty much in line with the expected increases based on 1970-2014 temperature increases[1,3,4]
- A 1.5°C temperature increase is likely within 8-12 years[5,20,21,22], implying almost a doubling of the current rate of temperature increase[6] (perhaps because it takes a while for atmosphere to adjust to the presence of greenhouse gases and about 50% of all emissions have occurred in the last 20 years).
- An temperature increase of 2.0°C by 2050 seems plausable[11,22]
- Climate models have done a pretty good job of predicting the actual temperature to date[7]
- The future temperature depends on CO2 emissions (anthropogenic and natural), non-CO2 radiative forcings, ocean and biosphere uptake of CO2, surface albedo changes, and clouds. Since none of these can be predicted with any precision, accurately estimating the temperature in 2100 is very problematic
- But future temperature increases are likely to be much more than the current models have predicted[8,9,10]
- If we don't do a good job of reducing emissions and we don't do any significant carbon capture and storage then we might expect an equilibrium temperature of at least 4° C in 2100[12]
- It is important to use high-end climate sensitivity because some studies have suggested that climate models have underestimated three major positive climate feedbacks. This would result in a temperature increase of about 5.5-5.7°C by 2100 for the IPCC's 2.0°C carbon budget.[10]

Added 1/15/2021

- The Global surface temperature in 2020 of +1.3°C was in a virtual dead-heat with 2016 for warmest year and the annual rate of change could be imcreasing[26] (*Note: the value for the increase depends on the base year used)*
- Earth's ability to absorb nearly a third of human-caused carbon emissions through plants could be halved within the next two decades at the current rate of warming[27,28]
- Threshold for dangerous warming will likely be crossed between 2026-2042[29,30]
- Warming already baked in will blow past climate goals[31]
- Warming could accelerate if coal burning is significantly reduced over a short period of time[32,33]

1

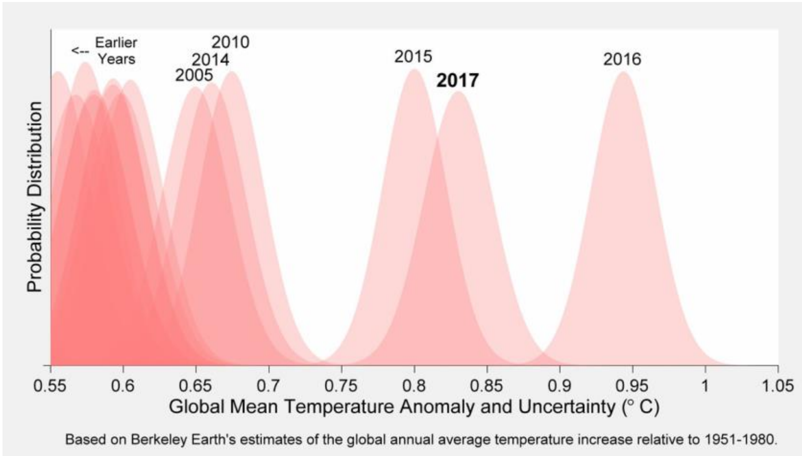


(Note: the source did not indicate what the temperature change is relative to)

https://www.skepticalscience.com/graphics.php?g=67

2

Global Mean Temperature Anomaly

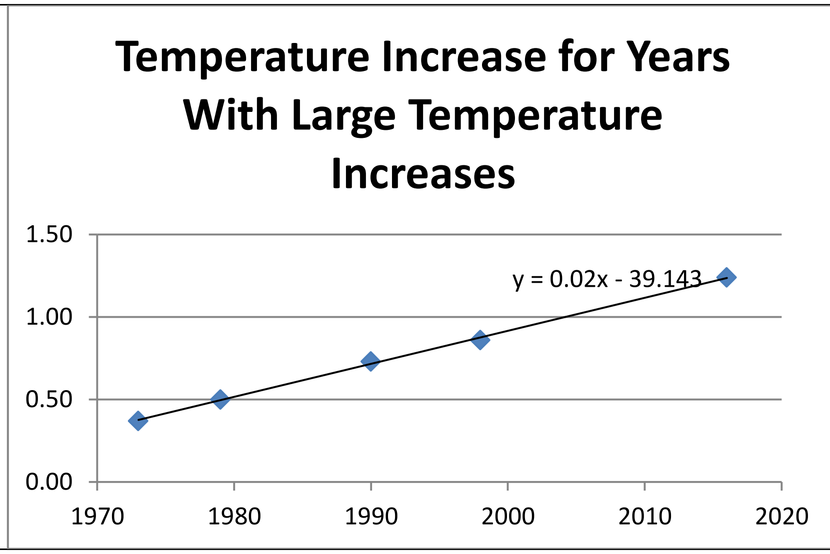


Berkeley Earth has a good summary of their 2017 results. http://berkeleyearth.org/global-s-2017/ ... This figure makes clear much warmer the last three years have been:

Source: Twitter - Gavin Schmidt @ClimateOfGavin

3

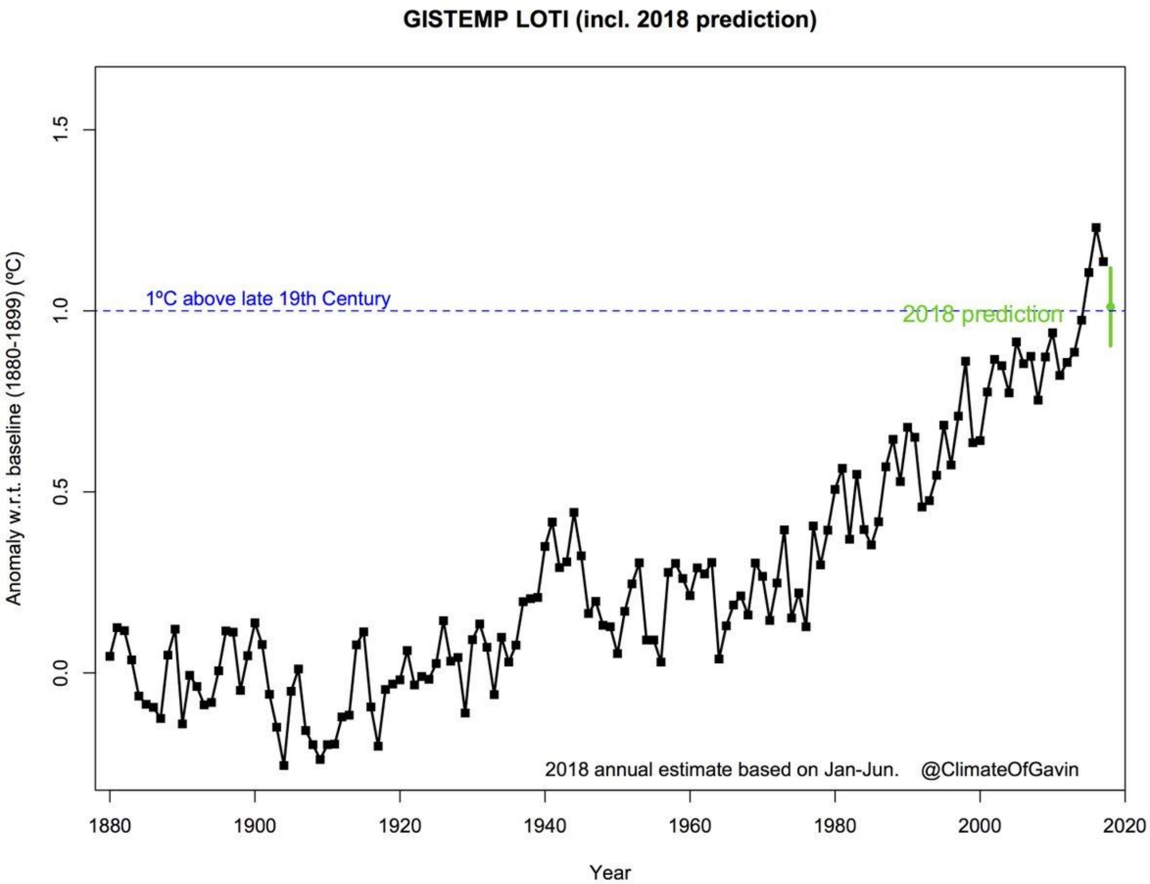
Year	Avg Temp (°C)
1973	0.37
1979	0.50
1990	0.73
1998	0.86
2016	1.24



By looking at the temperature increase for the five years since 1970 that had the largest temperature increase relative to the temperature increase of other "nearby" years, there appears to be a linear trend of about 0.2°C for the maximum expected temperature

https://www.ncdc.noaa.gov/cag/global/time-series/globe/land_ocean/1/12/1880-2018

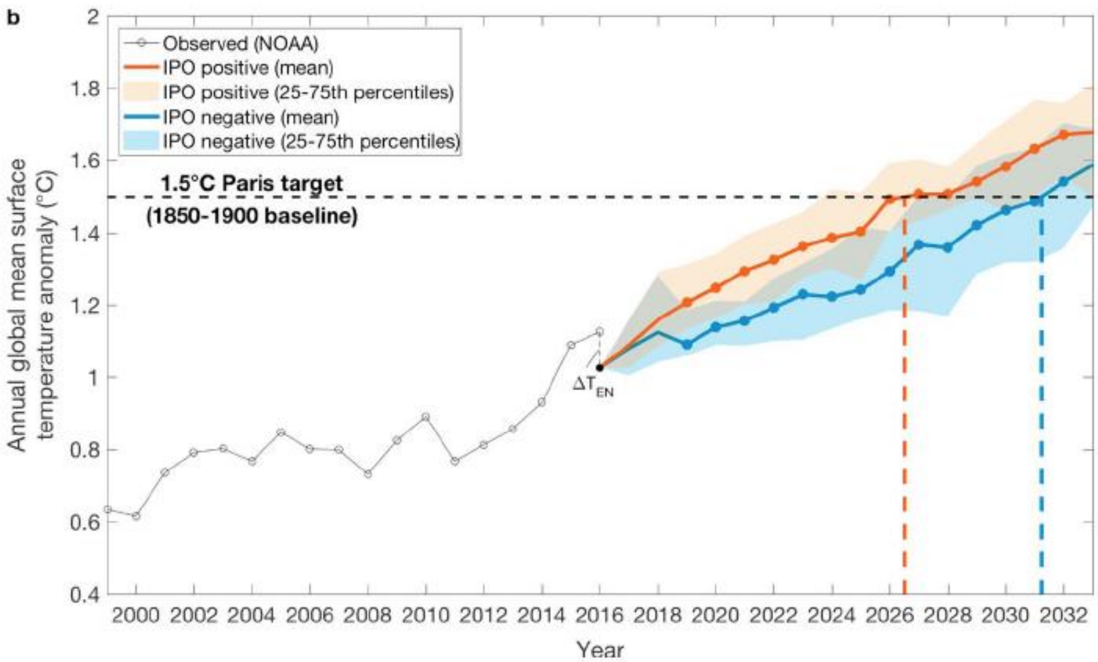
4 **2018 Global Average Temperature Estimate**



Gavin Schmidt - tweet

5 **1.5°C of Warming is Closer than We Imagine, Just a Decade Away**

HENLEY and KING: In 2017, Melbourne researchers Ben Henley and Andrew King published *Trajectories toward the 1.5°C Paris target: Modulation by the Interdecadal Pacific Oscillation* on the impact of the Interdecadal Pacific Oscillation (IPO) on future warming. The IPO is characterized by sea surface temperature fluctuations and sea level pressure changes in the north and south Pacific Ocean that occur on a 15-30 year cycle. In the IPO's positive phase, surface temperatures are warmer due to the transfer of ocean heat to the atmosphere. The IPO has been in a negative phase since 1999 but recent predictions suggest that it is now moving to a positive phase. The authors found that "in the absence of external cooling influences, such as volcanic eruptions, the midpoint of the spread of temperature projections exceeds the 1.5°C target before 2029, based on temperatures relative to 1850–1900". In more detail,"a transition to the positive phase of the IPO would lead to a projected exceedance of the target centered **around 2026**", and "if the Pacific Ocean remains in its negative decadal phase, the target will be reached around 5 years later, **in 2031**".



Projected temperature rises with IPO in positive mode (red) and negative mode (blue)   (Henley and King, 2017)

JACOB et al: the world is likely to pass the +1.5°C threshold around 2026 for RCP8.5, and "for the intermediate RCP4.5 pathway the central estimates lie in the relatively narrow window around 2030. In all likelihood, this means that a +1.5°C world is imminent."

KONG AND WANG: the threshold of 1.5°C warming will be reached in 2027, 2026, and 2023 under RCP2.6, RCP4.5, RCP8.5, respectively.

XU and RAMANTHAN: suggesting that the 1.5°C would be exceed around 2028.

ROGELJ et al: then SSP5 exceeds 1.5°C in 2029 and SSP4 by 2031.
https://www.resilience.org/stories/2018-04-05/1-5c-of-warming-is-closer-than-we-imagine-just-a-decade-away/

6

Temp Incr per Decade	Year							
	2017	2020	2025	2030	2035	2040	2045	2050
0.17	1.10	1.16	1.24	1.33	1.41	1.50	1.58	1.67
0.20	1.10	1.17	1.27	1.37	1.47	1.57	1.67	1.77
0.25	1.10	1.18	1.31	1.43	1.56	1.68	1.81	1.93
0.30	1.10	1.20	1.35	1.50	1.65	1.80	1.95	2.10
0.35	1.10	1.22	1.39	1.57	1.74	1.92	2.09	2.27

7 **How well have climate models projected global warming?**
By Zeke HausfatherTuesday, October 31, 2017

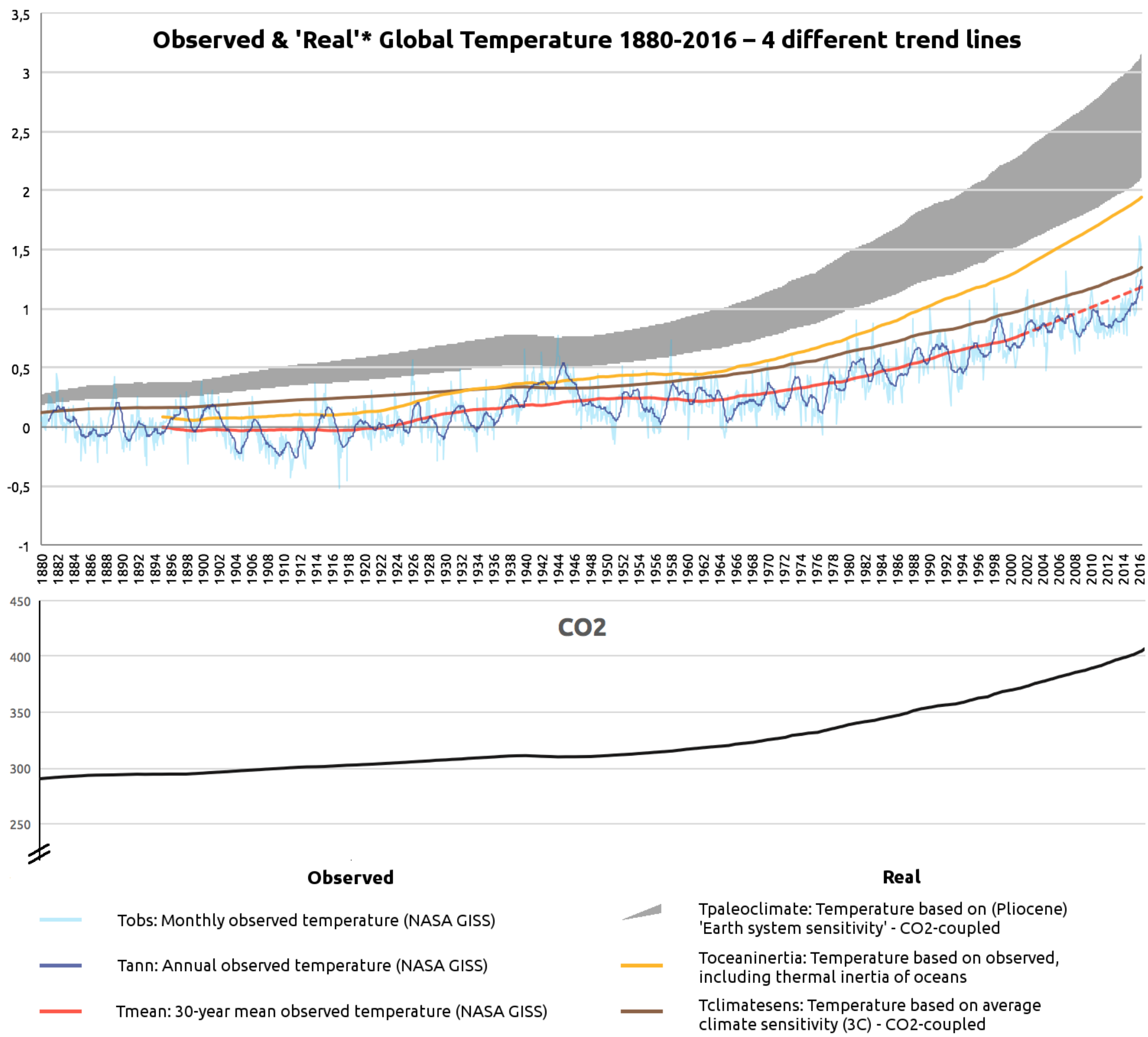
Climate models published since 1973 have generally been quite skillful in projecting future warming. While some were too low and some too high, they all show outcomes reasonably close to what has actually occurred, especially when discrepancies between predicted and actual CO2 concentrations and other climate forcings are taken into account.

Models are far from perfect and will continue to be improved over time. They also show a fairly large range of

	future warming that cannot easily be narrowed using just the changes in climate that we have observed. https://www.yaleclimateconnections.org/2017/10/how-well-have-climate-models-projected-global-warming/
8	**Observed vs 'Real' Global Temperature. What thermometers do & don't yet show!** Posted on **August 9, 2016** by **Rolf Schuttenhelm** **What we conclude about the global temperature trend:** 1. A large part of atmospheric warming is still masked by (shorter-lived) cooling factors and by climate system inertia – therefore **the CO2-coupled 'Real' Global Temperature is (much) higher than currently observed temperatures.** 2. **Recent global temperature records were no 'peaks'**, but rather *corrections* to a climatic temperature trend line that is (much) higher than the statistical trend line. 3. If atmospheric CO2 is stabilised around the current level (404 ppm) there is an uncertain, but possibly large amount of 'pipeline warming'. This **warming in the pipeline may lead to an additional temperature rise of more than 1 degree Celsius** – additional warming that will manifest itself after stabilisation of the CO2 concentration. The final temperature rise of the current CO2 concentration could be up to 2 or 3 times as high as the warming that is currently observed(!) 4. **The current atmospheric CO2 level is a dangerous overshoot** – to stay below internationally agreed climate targets (both 1.5 & 2 degrees) the **CO2 concentration** (that is currently still rising year by year) **should not be stabilised**, but should in fact be **lowered**. 5. If we keep measuring climate change by the observed rise in live temperatures and the Earth & climate system responses this temperature rise causes (including extreme weather events) **we keep underestimating the real scientific climate urgency.** The below graph shows 4 different temperature trends, against the observed rise of the atmospheric CO2 concentration: 1) observed temperatures (plus annual & 30-year average), an RGT trend based on 'consensus climate sensitivity', an RGT trend filtering ocean thermal inertia, and an RGT trend based on long-term 'Earth System Sensitivity, deduced from Pliocene & Eocene paleoclimate. It shows that at the current CO2 concentration, *atmospheric warming could still double*:

Global Temperatures. What thermometers do & *don't yet* show!

Global average temperature based on (1) actual observations (NASA GISS, light blue=monthly average, dark blue = year, red = 30 year), (2) climate sensitivity estimate (brown), (3) ocean thermal climate inertia estimate (orange), (4) Earth system sensitivity estimate (grey). The last three values are values for the extent of inevitable warming ('Real Global Temperature) due to inert climate processes if CO2 is stabilized at the level of that year.



NOTE: All temperatures are shown as deviations from 'late pre-industrial' - a baseline based on the climate average of 1880-1909. This baseline is supported by high-certainty measurements and is also used in political context. It is however not the 'real pre-industrial' climate, as in 1880-1909 atmospheric CO2 concentrations were already elevated (higher than pre-industrial value of 280 ppm that we use for climate sensitivity temperature reconstructions) and temperatures were slightly higher than before 1850 or before 1750 - the official onset of the industrial revolution (and start of the age of fossil fuels).

***)** The 'Real' Global Temperature (RGT) we define as the final ('inevitable') global average temperature that is reached if atmospheric CO2 is stabilised at any current level. Temperatures will continue to rise after this stabilisation for decades and possibly longer. We define 3 different values for RGT: an expected (CO2-coupled) temperature rise based on mean (model average & 'expert consensus') climate sensitivity, assuming a 3 degrees temperature rise for a doubling of atmospheric CO2 (we call this line Tclimatesens), an RGT value based on 'ocean thermal climate inertia', a decreasing portion of (constantly generated) atmospheric heat that is absorbed in the oceans, creating a warming time lag – here defined as a certain amount of additional warming that (within a period of 25 to 50 years) comes on top of observed temperatures once CO2 levels are stabilized (we call this line Toceaninertia), and an RGT value for 'Earth system sensitivity' – final (expected) warming that may occur once CO2 levels are stabilized for a longer time period, exceeding feedbacks speeds an time scales of 'regular' climate sensitivity and ocean thermal inertia. This Earth system sensitivity value is based on Pliocene

bits of science

DATA GRAVER

http://www.bitsofscience.org/observed-vs-real-global-temperature-series-conclusion-7180/

<table>
<tr><td>9</td><td>Global warming may be twice what climate models predict
July 5, 2018 by Alvin Stone, University of New South Wales

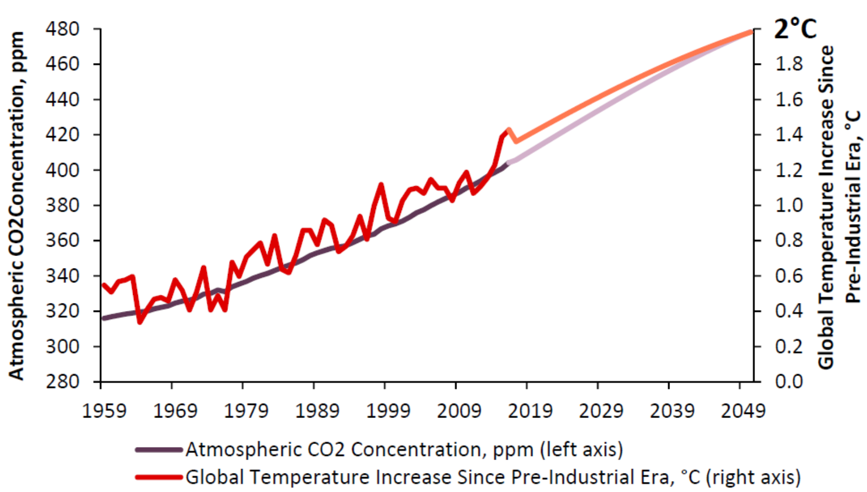
Future global warming may eventually be twice as warm as projected by climate models and sea levels may rise six metres or more even if the world meets the 2°C target, according to an international team of researchers from 17 countries.

The findings published last week in Nature Geoscience are based on observational evidence from three warm periods over the past 3.5 million years when the world was 0.5°C-2°C warmer than the pre-industrial temperatures of the 19th Century.

https://m.phys.org/news/2018-07-global-climate.html#jCp</td></tr>
<tr><td>10</td><td>What Lies Beneath (download PDF from https://www.breakthroughonline.org.au/)

Climate Sensitivity (Pages 22-23)

The work on existential climate risks by Xu and Ramanathan, cited above, is also important in assessing what is an appropriate climate sensitivity for risk-management purposes, for three reasons.
They say that:
1. Taking into account the biogeochemical feedbacks (such as less efficient land/ocean sinks, including permafrost loss) effectively increases carbon emissions to 2100 by about 20% and can enhance warming by up to 0.5°C, compared to a baseline scenario.
2. Warming has been projected to increase methane emissions from wetlands by 0–100% compared with present-day wetland methane emissions. A 50% increase in wetland methane emissions by 2100 in response to high-end warming of 4.1–5°C could add at least another 0.5°C.
3. It is important to use high-end climate sensitivity because some studies have suggested that climate models have underestimated three major positive climate feedbacks: positive ice albedo feedback from the retreat of Arctic sea ice; positive cloud albedo feedback from retreating storm track clouds in mid-latitudes; and positive albedo feedback by the mixed-phase (water and ice) clouds. When these are taken into account, the ECS is more than 40% higher than the IPCC mid-figure, at 4.5-4.7°C, before adding up to another 1°C of warming as described in 1. and 2. above. [Total warming would be expected to be in the range of 5.5-5.7°C]</td></tr>
<tr><td>11</td><td>The Race of Our Lives Revisited
Exhibit 15: Atmospheric CO2 and Temperature Increase since Pre-Industrial Era



As of 9/30/17
Source: National Oceanic and Atmospheric Administration, GMO
Data from 2016-2050 is estimated or forecast.
https://www.advisorperspectives.com/commentaries/2018/08/09/the-race-of-our-lives-revisited</td></tr>
</table>

12 Given the following:

9.86	**2015 Fossil Fuel Emissions (GTC)**
1.6	**2015 land use emissions (GTC)**
2070	**Year when land use emissions reach zero**
0.029	**Land use decline/year (GTC)**
1%	**Annual increase in FF emissions to 2025**
1%	**Annual decrease in FF emissions after 2025**
718	**GTC of fossil fuel and land use emissions (calculated)**
0.8	**Radiative Forcing in 2100 from other than CO2 (W/m-2)**
	Ocean and biosphere uptake similar to MAGICC and CROADS
3.4	**Climate sensitivity to account for natural feedbacks**

Then we should expect an equilibrium temperature of about 4.6° C in 2100 (Note that the same result is obtained with a climate sensitivity of 3.0 and natural feedbacks of 100 GTC)

		Climate Sensititivity	3.4														
		CO2 Emissions															
		100	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900
Non-CO2 RF	**0.0**	1.11	1.43	1.58	1.74	1.90	2.06	2.22	2.37	2.53	2.69	2.85	3.01	3.16	3.32	3.48	3.64
	0.1	1.19	1.52	1.68	1.84	2.00	2.16	2.32	2.48	2.64	2.81	2.97	3.13	3.29	3.45	3.61	3.77
	0.2	1.28	1.61	1.77	1.94	2.10	2.27	2.43	2.59	2.76	2.92	3.09	3.25	3.42	3.58	3.74	3.91
	0.3	1.37	1.70	1.87	2.04	2.21	2.37	2.54	2.71	2.87	3.04	3.21	3.38	3.54	3.71	3.88	4.05
	0.4	1.46	1.80	1.97	2.14	2.31	2.48	2.65	2.82	2.99	3.16	3.33	3.50	3.67	3.84	4.02	4.19
	0.5	1.55	1.90	2.07	2.25	2.42	2.59	2.77	2.94	3.11	3.29	3.46	3.63	3.81	3.98	4.16	4.33
	0.6	1.64	2.00	2.18	2.35	2.53	2.71	2.88	3.06	3.24	3.41	3.59	3.77	3.94	4.12	4.30	4.47
	0.7	1.74	2.10	2.28	2.46	2.64	2.82	3.00	3.18	3.36	3.54	3.72	3.90	4.08	4.26	4.44	4.62
	0.8	1.84	2.20	2.39	2.57	2.75	2.94	3.12	3.31	3.49	3.67	3.86	4.04	4.22	4.41	4.59	4.77
	0.9	1.94	2.31	2.50	2.68	2.87	3.06	3.25	3.43	3.62	3.81	3.99	4.18	4.37	4.55	4.74	4.93
	1.0	2.04	2.42	2.61	2.80	2.99	3.18	3.37	3.56	3.75	3.94	4.13	4.32	4.51	4.70	4.90	5.09
	1.1	2.14	2.53	2.72	2.92	3.11	3.30	3.50	3.69	3.89	4.08	4.28	4.47	4.66	4.86	5.05	5.25
	1.2	2.24	2.64	2.84	3.03	3.23	3.43	3.63	3.83	4.02	4.22	4.42	4.62	4.82	5.01	5.21	5.41
	1.3	2.35	2.75	2.95	3.16	3.36	3.56	3.76	3.96	4.16	4.37	4.57	4.77	4.97	5.17	5.37	5.58
	1.4	2.46	2.87	3.07	3.28	3.49	3.69	3.90	4.10	4.31	4.51	4.72	4.92	5.13	5.33	5.54	5.74
		Equilibrium Temperature															

Note that for CS=3, NonCO2RF=0.8, CO2 emissions of 525 GTC result in an equilibrium temperature of about 3°C and for CS=3.4, NonCO2RF=0.8, CO2 emissions of 420 GTC result in an equilibrium temperature of about 3°C. Since natural emissions are apt to be at least 100 GTC[1] (for a temperature increase less than 2°C), it seems logical to assume that a climate sensitivity of 3 where natural emissions are included is equivalent to a climate sensitivity of 3.5 where natural emissions are not included (and the "equivalence" is apt to be wider for higher temperatures)

http://ccdatacenter.org/documents/CO2EmissionsBudgets.pdf

13

Committed Global Temperature Increases (likely an exaggeration - included because it has some interesting points)

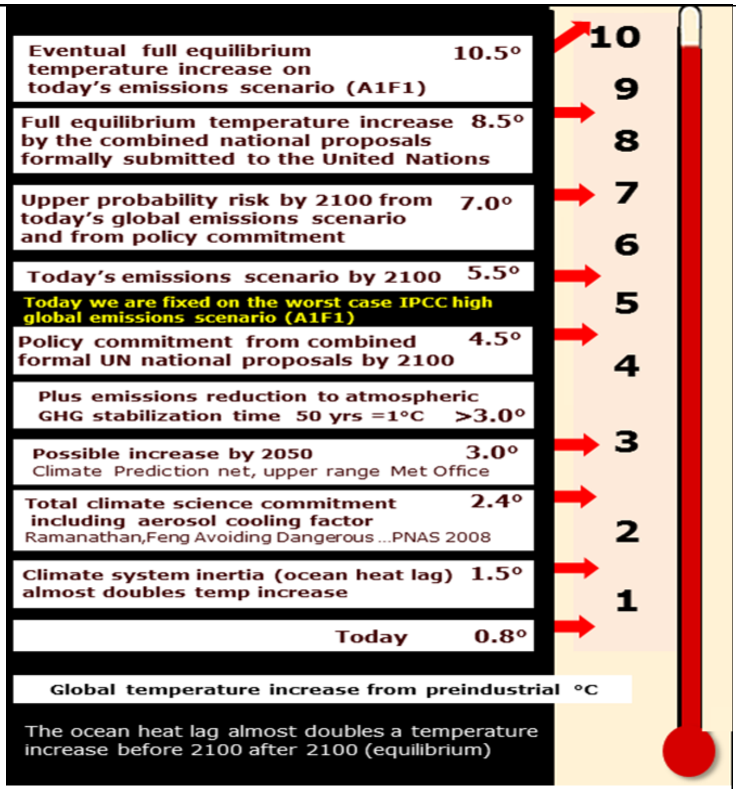
Today's full committed globalwarming due to climate science is **2.4°C** (Ramanathan, Feng Avoiding Dangerous Climate interference ... PNAS 2008) and warming will continue for over **1000 years**

•0.8°C today's surface temperature increase

•0.7°C 'hidden' deferred warming from the ocean heat lag. The ocean heat lag commits any temperature increase before 2100 to almost double after 2100 at temperature equilibrium.

•0.9°C 'hidden' deferred warming due to aerosol cooling that will be 'unmasked' when fossil air pollution or fossil energy production stops

• Plus another 1.0°C which is the fastest time from emergency emissions reduction to atmospheric GHG stabilization.



https://www.climateemergencyinstitute.com/committed_global_warming_basic_science.html

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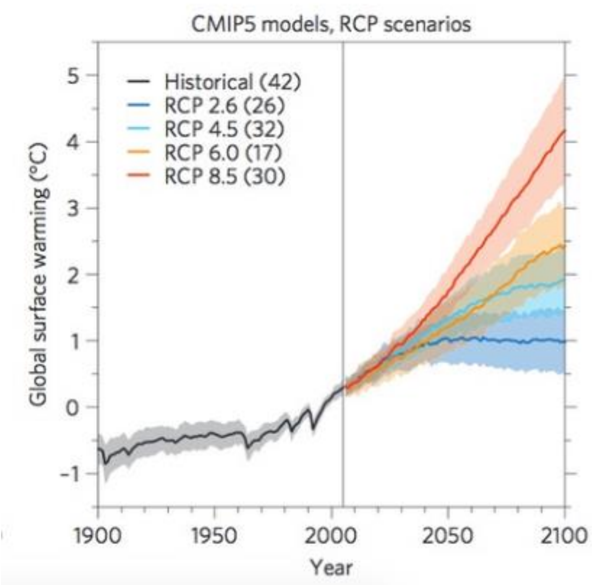


Radiative Forcing	Temperature Increase (°C)		
	50%	66%	83%
2.6	1.55	1.84	2.14
4.5	2.29	2.60	2.90
6.0	2.64	3.09	3.53
8.5	4.18	4.62	5.06

Radiative Forcing	Implied Climate Sensitivity* (For an Equilibrium Temp)		
	50%	66%	83%
2.6	2.21	2.63	3.05
4.5	1.88	2.13	2.38
6.0	1.63	1.90	2.18
8.5	1.82	2.01	2.20

* climate sensitivity = 3.7 * Temp Increase /Radiative Forcing
(Note: 66% column is average of 50% and 83% columns)

15	**Ecosystems across Australia are collapsing under climate change** 23/07/2018 The Great Barrier Reef has become a notorious victim of climate change. But it is not the only Australian ecosystem on the brink of collapse Our research, recently published in Nature Climate Change, describes a series of sudden and catastrophic ecosystem shifts that have occurred recently across Australia. These changes, caused by the combined stress of gradual climate change and extreme weather events, are overwhelming ecosystems' natural resilience. We identified ecosystems across Australia that have recently experienced catastrophic changes, including: • kelp forests shifting to seaweed turfs following a single marine heatwave in 2011; • the destruction of Gondwanan refugia by wildfire ignited by lightning storms in 2016; • dieback of floodplain forests along the Murray River following the millennial drought in 2001–2009; • large-scale conversion of alpine forest to shrubland due to repeated fires from 2003–2014; • community-level boom and bust in the arid zone following extreme rainfall in 2011–2012, and • mangrove dieback across a 1,000km stretch of the Gulf of Carpentaria after a weak monsoon in 2015-2016. Of these six case studies, only the Murray River forest had previously experienced substantial human disturbance. The others have had negligible exposure to stressors, highlighting that undisturbed systems are not necessarily more resilient to climate change. http://www.climatechangenews.com/2018/07/23/ecosystems-across-australia-collapsing-climate-change/
16	**Saving Earth: Don't Fall Into Climate Change Fatalism** Peter H. Gleick 08/01/2018 It's too late to stop severe climate change – indeed we see it around us. But it is absolutely not too late to slow the rate of climate change, to accelerate the transition away from coal, and then oil, and then natural gas to the diverse and increasingly inexpensive and effective suite of renewable energy options available to us. We can, and must, still act. As the Times piece notes, we've lost the opportunity to prevent one degree Celsius of warming and without prompt and dramatic efforts almost certainly cannot prevent two degrees of warming. That's bad enough: It's probably sufficient to destroy the Arctic ice cap, most shallow tropical reefs, much of the snowpack in the world's mountain ranges and lead to more extreme floods and droughts. But continued inaction will lead to much worse. Three or four degrees warming – which by the way was enough to mark the difference between planetary ice ages and warm interglacial periods – would wipe out all major coastal cities that can't spend the literally hundreds of billions of dollars or more needed to build massive seawalls, destroy dozens of low-lying island nations, and make vast areas near the equator brutally – and perhaps unbearably – hot. Five degrees is simply unthinkable. The good news is that these doomsday scenarios are not inevitable. Progress is being made almost everywhere, except at the national level of the U.S. Other nations, many U.S. states, local governments, responsible companies and individuals are moving forward. Emissions have flattened over the last several years and are starting to come down in many places. The delays of the past 40 years have committed the planet to unprecedented changes and will impose severe costs on all of us, especially on the poorest populations without the resources to adapt. But even more extreme costs can still be prevented if our politicians and the public can put aside blind ideology, anti-science rhetoric and short-term thinking for the sake of our children and the planet. https://www.huffingtonpost.com/entry/opinion-gleick-new-york-times-climate-change_us_5b61fafbe4b0b15aba9f3959

17 **EARTH WILL START BECOMING A DESERT BY 2050 IF GLOBAL WARMING ISN'T STOPPED, STUDY SAYS**

BY LEAH THOMAS ON 1/2/18 AT 4:14 PM

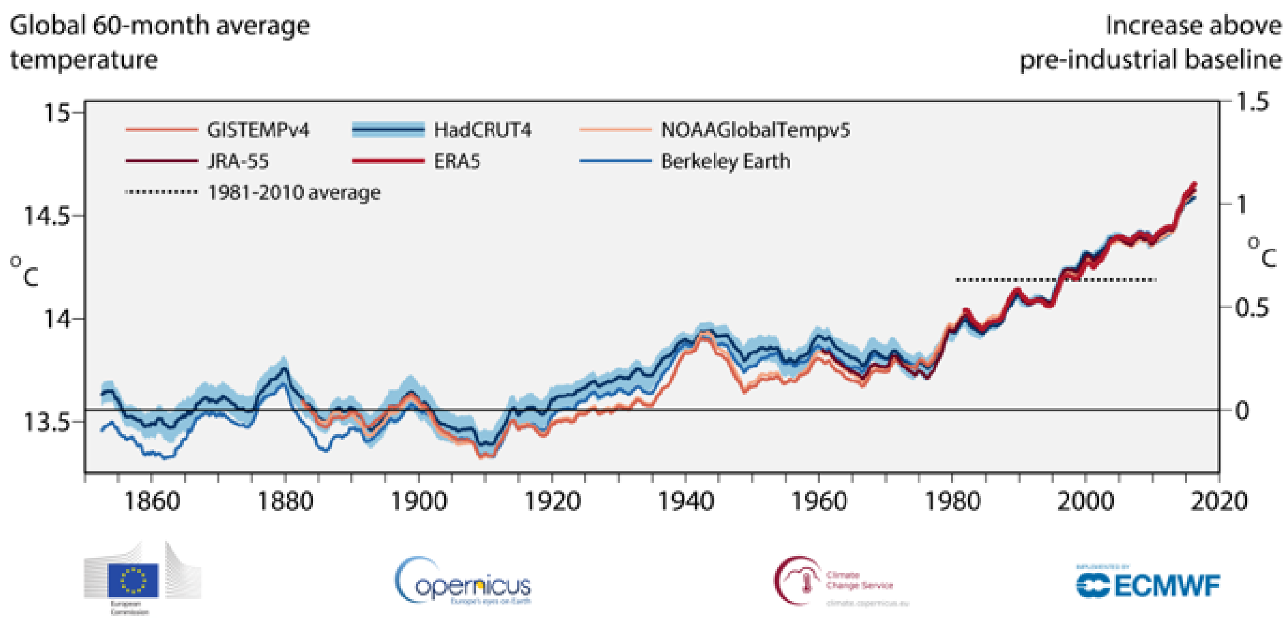
More than 25 percent of the Earth will experience serious drought and desertification by the year 2050 if the attempts made by the Paris climate agreement to curb global warming are not met, according to a new study by the journal Nature Climate Change.

The study, which was published on Monday, claims that if the Earth's average yearly temperature is raised by 2 degrees Celsius (3.6 degrees Fahrenheit) in the next 32 years, the areas of the world experiencing "aridification," or drying of the planet, will increase.

"Our research predicts that aridification would emerge over about 20 to 30 percent of the world's land surface by the time the global mean temperature change reaches 2 degrees Celsius," said Manoj Joshi, the lead researcher of the study. "But two-thirds of the affected regions could avoid significant aridification if warming is limited to 1.5 degrees Celsius [2.7 degrees Fahrenheit]."

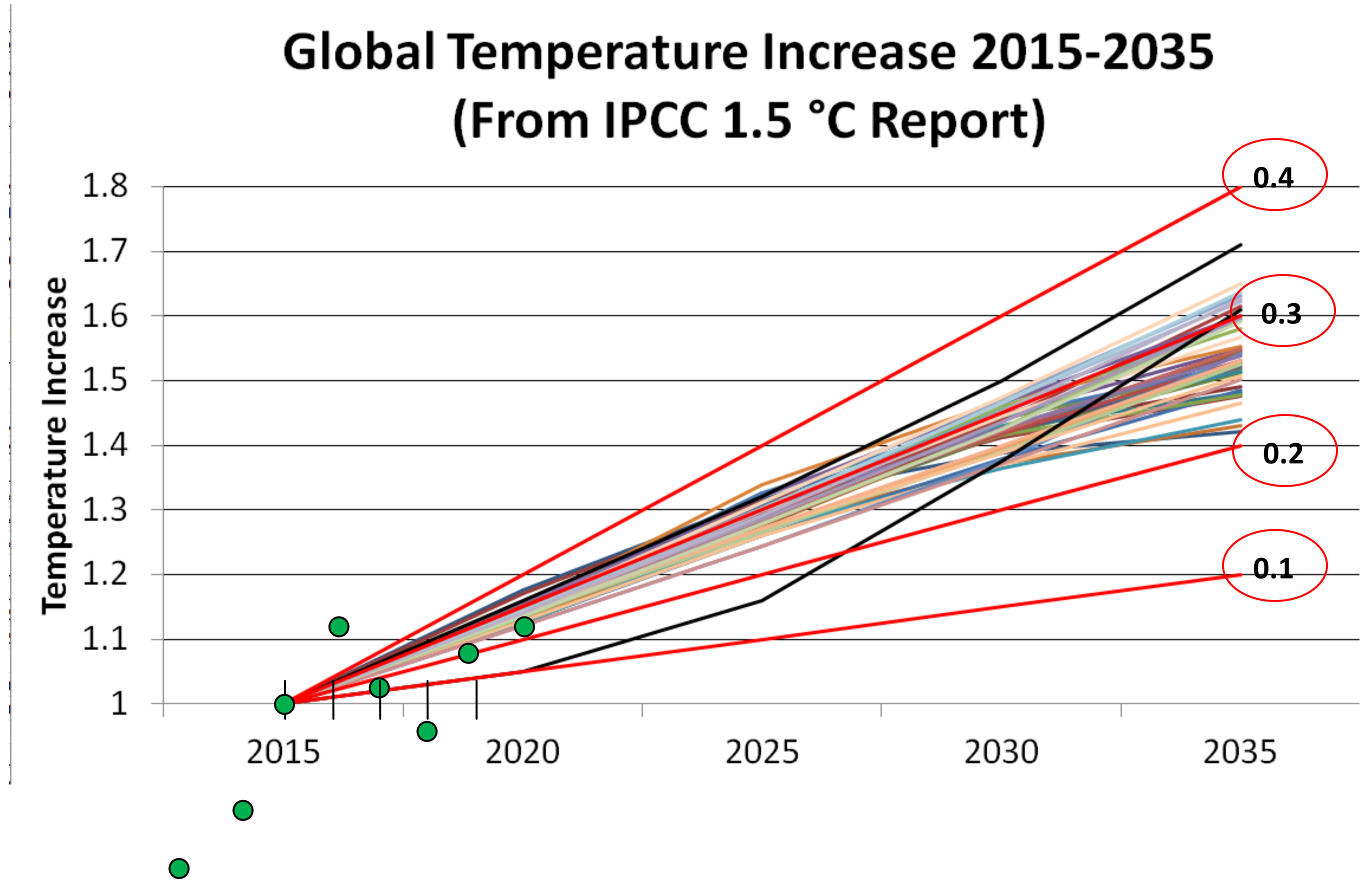
http://www.newsweek.com/earth-desert-2050-global-warming-768545

18 Note the sharp upturn in the temperature increase in the last 5-10 years. Most IPCC scenarios show this trend continuing through 2050



https://community.windy.com/topic/10863/copernicus-report-2019-was-the-second-warmest-year-and-the-last-five-years-were-the-warmest-on-record

19



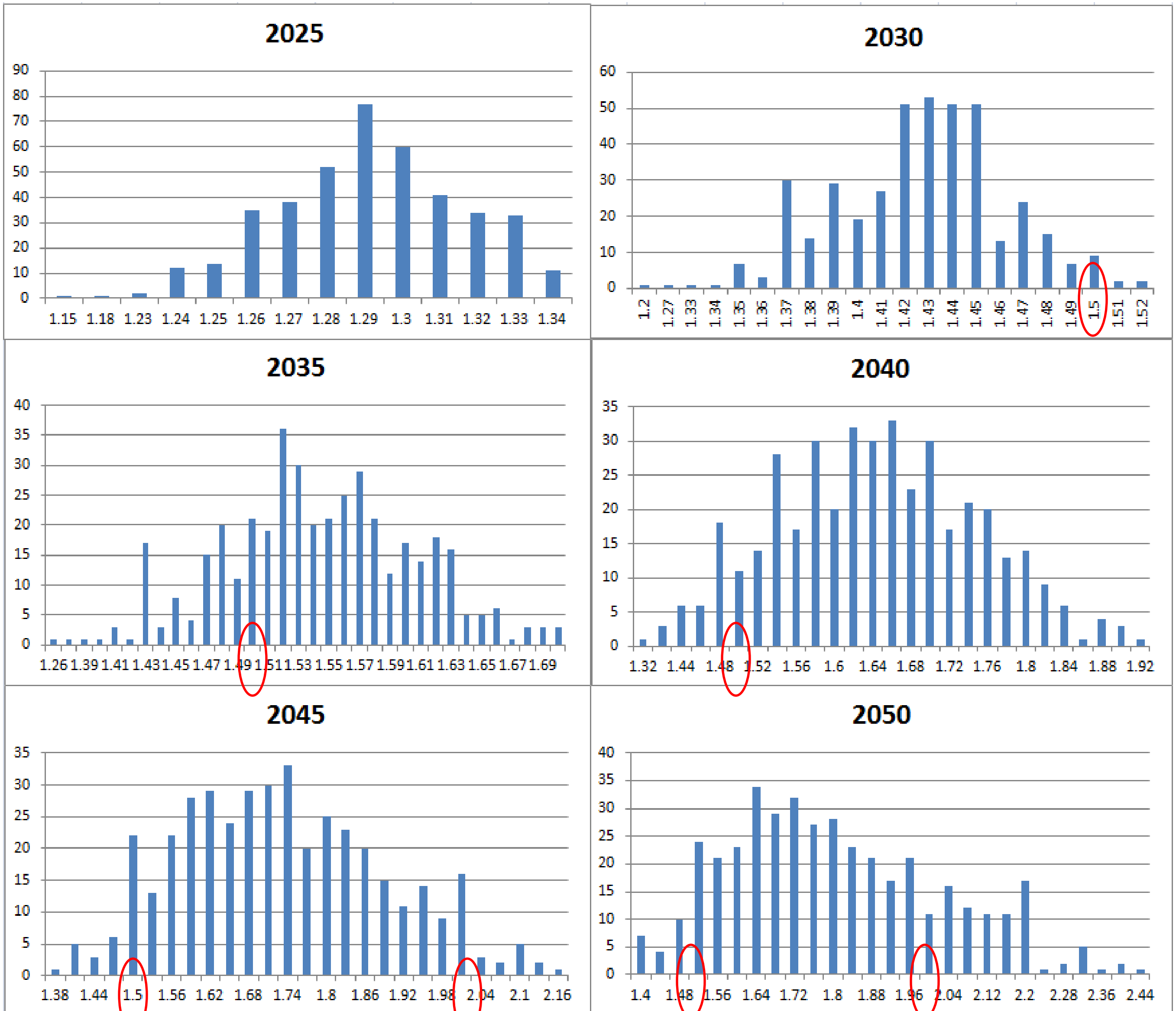
Notes:

- Green dots - Tempearature increases for 2013-2019: 0.78, 0.86, 1.00, 1.12, 1.03, 0.95, 1.08°C; 2020: 1.12°C tied with 2016 (http://www.columbia.edu/~jeh1/mailings/2021/20210114_Temperature2020.pdf)
- IPCC 1.5°C Report data (all but the black and red lines) are from 10 percent of the 410 scenarios, selected by sorting the scenarions by 2035 temperaure incease and selecting every tenth scenario, strarting the with the fifth scenario (and adjusted so all 2015 temperatures were 1.0°C) (the average rate of increase is about .25°C/decade)
- Black lines are from an estimate by *Henley and King, 2017,* adjusted so all 2015 temperatures were 1.0°C (https://www.resilience.org/stories/2018-04-05/1-5c-of-warming-is-closer-than-we-imagine-just-a-decade-away/)
- Red lines are decadal temperature increases of 0.1, 0.2, 0.3, and 0.4°C
- For reference purposes, the following table shows the decadal temperature increase for the specified time period (data from http://data.giss.nasa.gov/gistemp/graphs_v3/Fig.A2.txt)

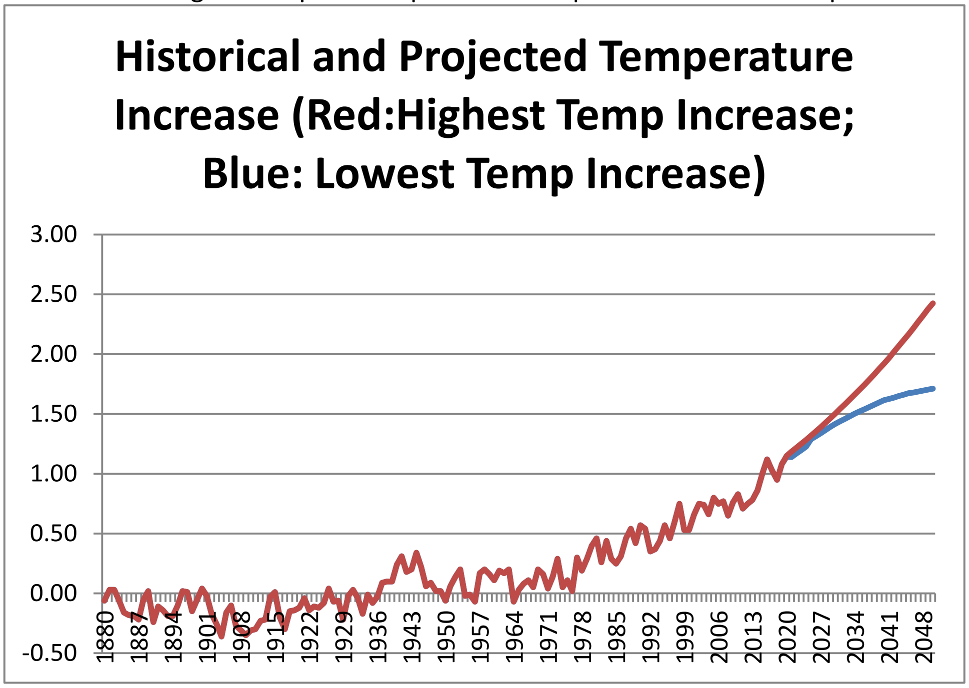
Time Period	Decadal Temp Increase
1900-2019	0.092
1970-2019	0.183
2008-2019	0.375
2011-2019	0.473

Source: Spreadsheed associated with the IPCC 1.5°C Report

20 Counts of scenarios where the rounded temperature has the spedified value in the specified year.
Note that over half of the scenarios show the temperature exceeding 1.5°C by 2035 and almost all show the temperature exceeding 1.5°C by 2040
(red circles indicate 1.5°C and 2.0°C thresholds)

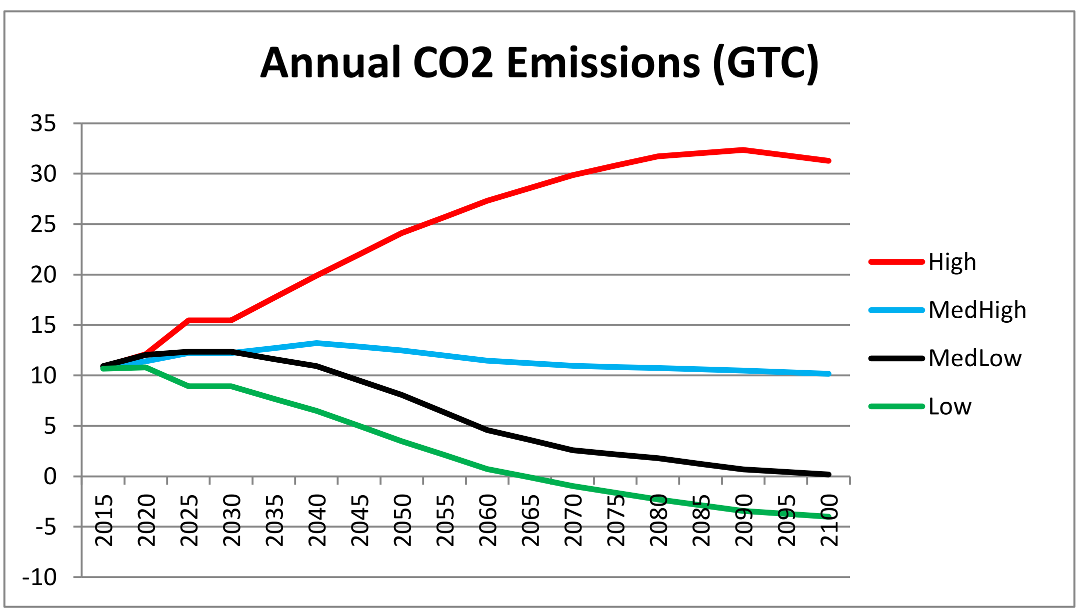


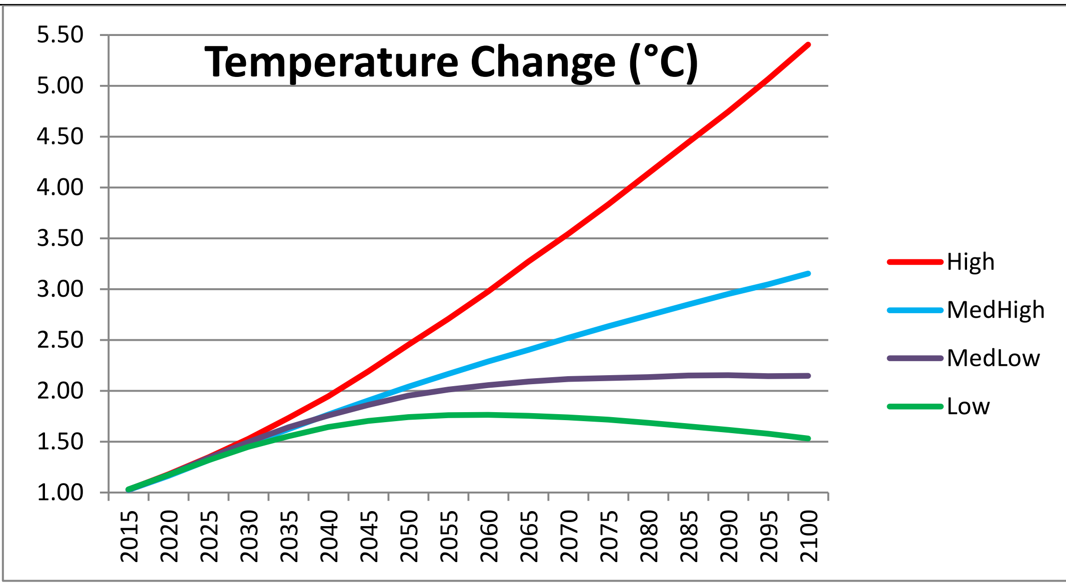
21 **Source:** Spreadsheed associated with the IPCC 1.5°C Report
This graph shows, for the 410 scenarios, the upper and lower ranges of the expected temperature increase
Note that the higher temperature prediction is quite close to an extrapolation of the current trend



22 Data from the following scenarios were used to create the accompanying graphs and chart:

	Model	Scenario
High	WITCH-GLOBIOM 3.1	SSP5-Baseline
MedHigh	AIM/CGE 2.0	SSP5-60
MedLow	IMAGE 3.0.1	SSP5-34
Low	MESSAGEix-GLOBIOM 1.0	CD-LINKS_NPi2020_1000

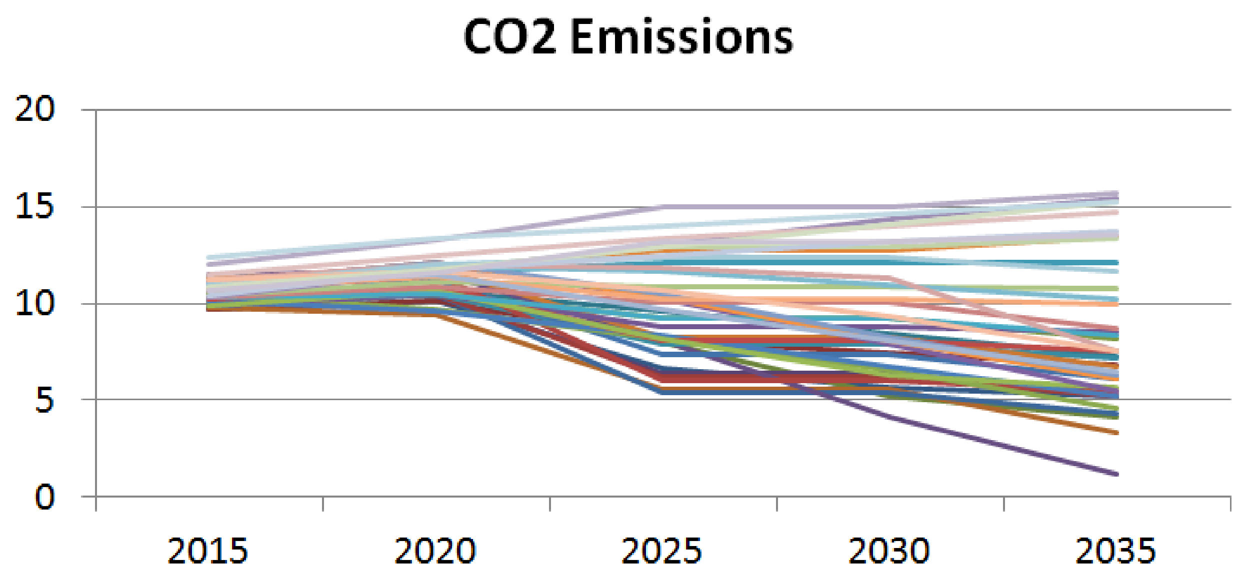




	2100 Cumulative and Annual Values				2020 Average
	High	**MedHigh**	**MedLow**	**Low**	
Temperature Increase	5.40	3.15	2.15	1.53	1.17
CO2 Atmos Conc 2100	1070	660	507	413	418
CO2e Atmo Conc 2100	1489	775	550	440	471
Emissions (GTC and MT)					
CO2 (Annual)	31.3	10.2	0.2	-4.0	11.6
CO2 (Cumulative 2015-2100)	2111	991	535	216	
CH4 (Annual)	787	326	167	115	386.8
N20 (Annual)	15.9	12.5	9.0	6.4	10.5
N2O (Cumulative 2015-2100)	1236	966	818	724	
Radiative Forcing in 2100 (W/m2)					
CO2	7.24	4.63	3.22	2.13	2.21
CH4 (Methane)	0.90	0.44	0.27	0.21	0.54
N2O	0.43	0.36	0.31	0.28	0.20
Aerosol	-0.54	-0.37	-0.33	-0.35	-0.91
Other GHGs	0.97	0.45	0.20	0.22	0.80
Total RF	**9.00**	**5.50**	**3.67**	**2.48**	2.84

23

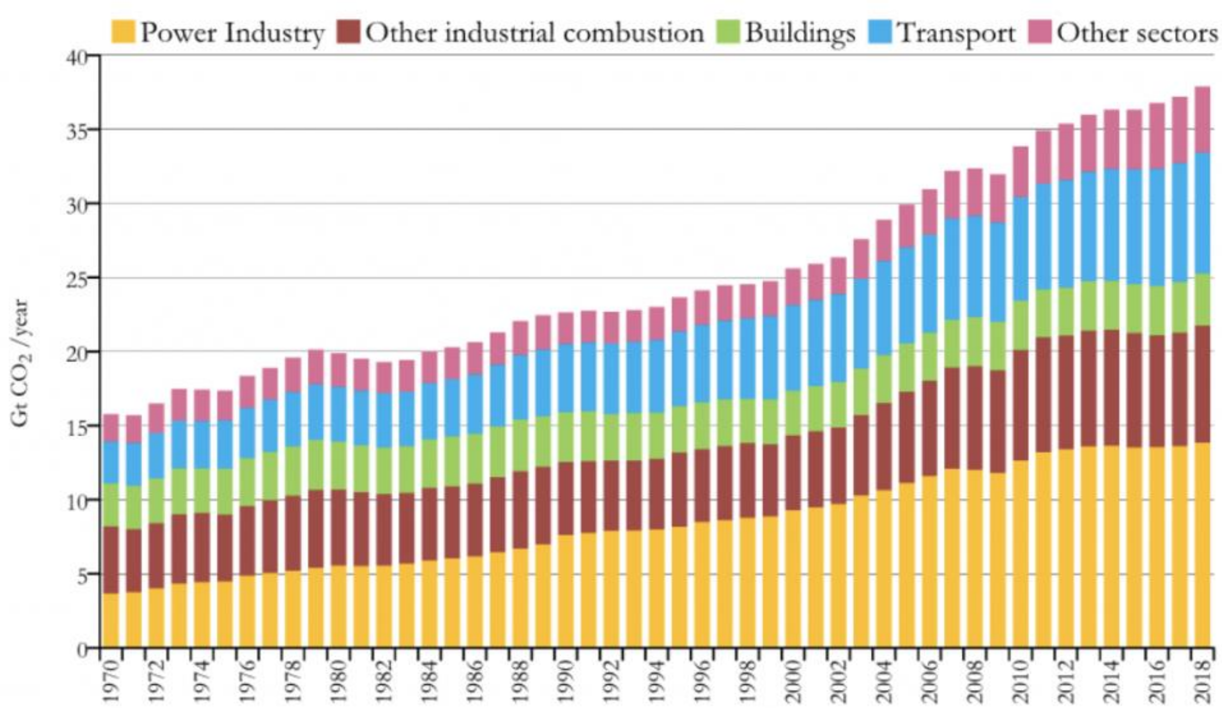
- IPCC 1.5°C Report data are from 10 percent of the 410 scenarios, selected by sorting the scenarions by 2035 temperaure incease and selecting every tenth scenario, strarting the with the fifth scenario
- Note the large variance for 2015.
- CO2 emissions are likely to increase for at least the next 10 years, so we a are likely on the upper end of the temparature projections



24

https://www.thegwpf.com/the-greta-effect-global-co2-emissions-increased-by-1-9-in-2018/

Figure 2. Total global annual emissions of fossil CO_2 in Gt CO_2/yr by sector. Fossil CO_2 emissions include sources from fossil fuel use, industrial processes and product use (combustion, flaring, cement, steel, chemicals and urea).



2015: 2016: 2017: 2018: 2019: (adjusted for 2019=36.8, a .6% increase over 2018

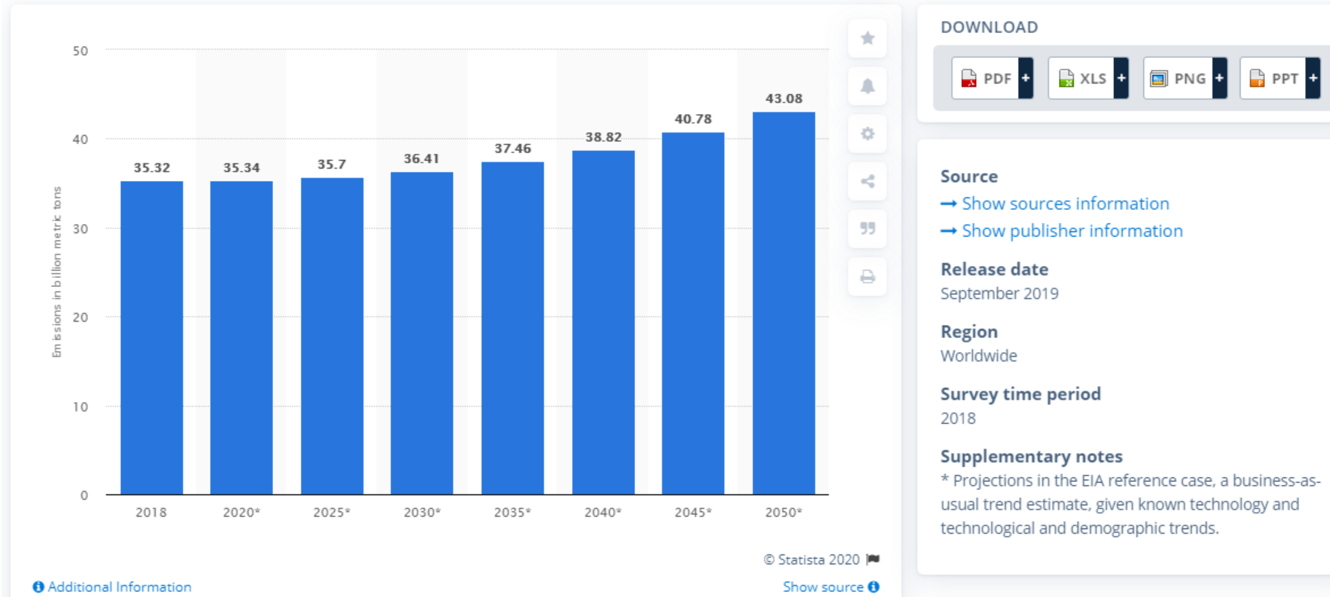
35.1 35.5 35.9 36.6 36.8

25

https://www.statista.com/statistics/263980/forecast-of-global-carbon-dioxide-emissions/

Forecast of carbon dioxide emissions worldwide from 2018 to 2050

(in billion metric tons)



26A

Global Temperature in 2020 14 January 2021 James Hansen

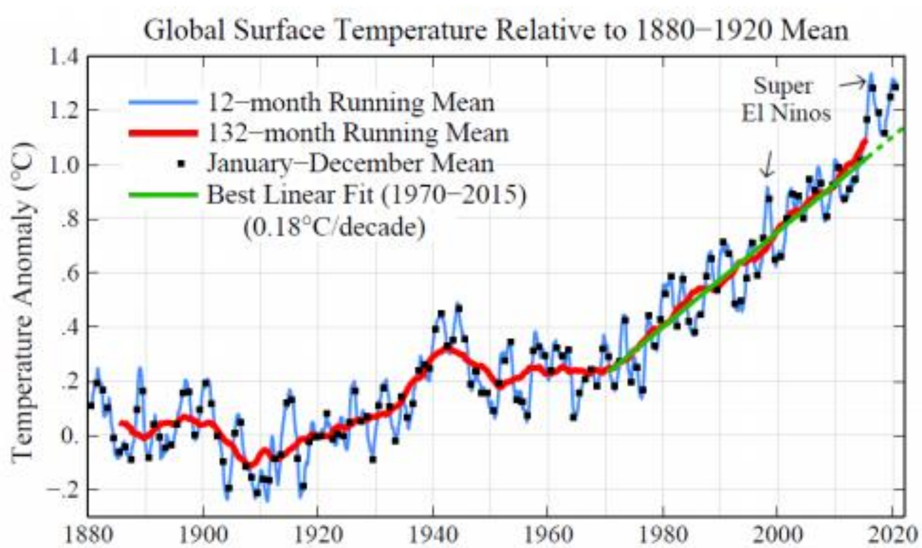
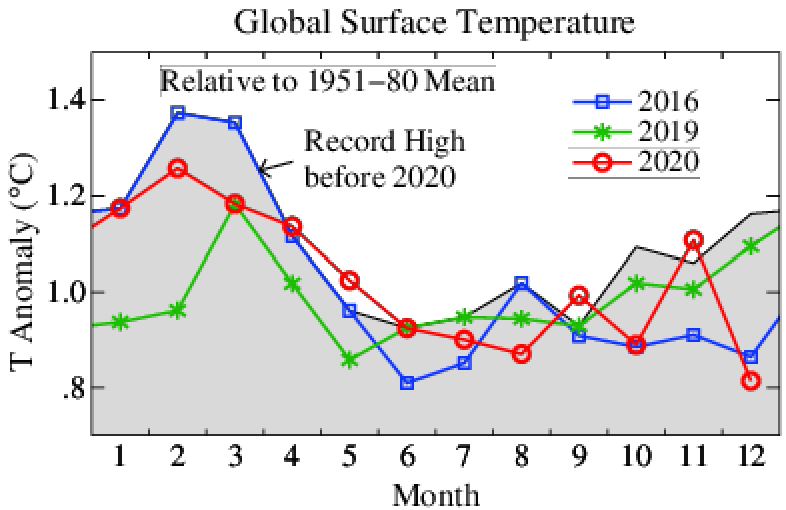


Fig. 1. Global surface temperatures relative to 1880-1920 based on GISTEMP data, which employs GHCN.v4 for meteorological stations, NOAA ERSST.v5 for sea surface temperature, and Antarctic research station data[1].

The other well-measured climate forcing is change of solar irradiance, which decreased during the 2015-2020 period of accelerated warming by an amount such that the growth rate of the sum of GHG and solar forcings slowed during that period. This has led to an inference that the one large unmeasured climate forcing, human-made atmospheric aerosols, likely became less negative (decreased aerosol amount) during that period.7

The alternative is that unforced variability of global temperature is larger than what is suggested by observations in the prior half century (Fig. 1). Observed global temperature over the next year or two will help inform us whether the apparent acceleration of global warming is significant. The current La Niña (Figures 4 and 9) is moderately strong, so this year – 2021 – should be notably cooler than 2020. If global temperature falls back below the trend line, the apparent acceleration may be unforced variability.

In any case, long-term warming will continue because of the continued large annual increases of the greenhouse

	gas climate forcing (Fig. 8). The greenhouse warming will be abetted by solar irradiance; solar minimum was reached in 2019, so irradiance should be increasing for the next several years. http://www.columbia.edu/~jeh1/mailings/2021/20210114_Temperature2020.pdf
26B	 **http://www.columbia.edu/~mhs119/Temperature/2015-2020line.png**
27	**Earth to reach temperature tipping point in next 20 to 30 years, new study finds** Jan 2021 https://phys.org/news/2021-01-earth-temperature-years.html
28	Land Absorbs Carbon Now—But It Could Emit It in Just a Few Decades https://earther.gizmodo.com/land-absorbs-carbon-now-but-it-could-emit-it-in-just-a-1846053001
29	Climate change: Threshold for dangerous warming will likely be crossed between 2027-2042 Scientists introduce a new way to predict global warming, reducing uncertainties considerably December 21, 2020 https://www.sciencedaily.com/releases/2020/12/201221160425.htm
30	Analysis: When might the world exceed 1.5C and 2C of global warming? https://www.carbonbrief.org/analysis-when-might-the-world-exceed-1-5c-and-2c-of-global-warming
31	Study: Warming already baked in will blow past climate goals A new study says the amount of global warming already baked into the air because of past carbon pollution is enough to blow past internationally agreed upon climate limits By SETH BORENSTEIN AP Science Writer January 4, 2021, 8:19 PM https://abcnews.go.com/Technology/wireStory/study-warming-baked-blow-past-climate-goals-75044132
32	Global Warming Acceleration 14 December 2020 James Hansen and Makiko Sato Abstract. Record global temperature in 2020, despite a strong La Niña in recent months, reaffirms a global warming acceleration that is too large to be unforced noise – it implies an increased growth rate of the total global climate forcing and Earth's energy imbalance. Growth of measured forcings (greenhouse gases plus solar irradiance) decreased during the period of increased warming, implying that atmospheric aerosols probably decreased in the past decade. There is a need for accurate aerosol measurements and improved monitoring of Earth's energy imbalance. How large is the aerosol forcing? In recent IPCC reports the GCMs (global climate models) tended to use aerosol forcings in the range -0.5 W/m^2 to -1.0 W/m^2, despite the fact that the IPCC radiative forcing chapters suggest a larger (more negative) aerosol forcing, with a direct aerosol forcing ~ -0.5 W/m^2 and an indirect aerosol forcing (via cloud effects) ~ -1 W/m^2, with large uncertainty bars. Consistent with the

	radiative forcing chapters, we (Hansen et al, 2011) made a strong case that the actual aerosol forcing is -1.6 ±0.3 W/m^2. We also infer why most GCMs (including the GISS model) "need" a smaller aerosol effect – if they want to match observed global warming in the past century. The reason is that the models mix heat too efficiently into the ocean – so to match observed warming the models need a larger net forcing, which they achieve by omitting some of the negative aerosol forcing. Is this important? Yes. It means that the little blip of extra warming that we got in the past five years is only a down payment on the penalty that young people will pay for our Faustian bargain. Mephistopheles is coming, but it is our grandchildren that he will be dragging off https://mailchi.mp/caa/global-warming-acceleration
33	Dr. James E Hansen - Nitrogen and Aerosol Masking Dec 15, 2020 (7 minutes) https://www.youtube.com/watch?v=uii6sBAUrc0&list=PLe6EP38qqR0b8qIzgC1LDdmcg0IqUJMrM&index=33