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Timing of Benchmark Climate Temperatures

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TIMING and *IMPACTS* of Climate Change

or, more specifically,

Timing of Temperature Increases
and
Impacts anticipated at those Temperatures

Timing and Impacts are the topics of this **series**. These are essential to discuss, because the quantities of emissions and actual atmospheric, ocean, and land temperatures are both surging upwards. Perhaps changes are so slow that they don't matter - impacts are no big deal. Perhaps the opposite is the case.

We will tackle TIMING first. **The question for today is:**

What is a best estimate of how quickly much-discussed temperatures may be experienced?

Let's examine actual data and trends in emissions and temperatures to develop a **Best Estimate of Timing** - *one we give personal credence to.*

A timeframe that seems so realistic we will decide on our personal responses in that context.

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Climate Science Study Group

Approximate "Cheat Sheet":

1 meter → 3 feet **1 degree Celsius (^{0}C)** → 2 degree Fahrenheit (^{0}F)
ppm = parts per million **CO_2** = Carbon Dioxide
1 tonne = 1000 kilograms = 2205 pounds **1 gigatonne (1 Gt)** = 1 billion tonnes
1 trillion tonnes (1Tt) = 1000 gigatons

Timing of Benchmark Climate Temperatures

EMISSIONS and TEMPERATURES are key measurements of something we can control (emissions) and how the planet responds - which we cannot control (temperature). They are linked as CAUSE-EFFECT, and are the basis of this study to ascertain TIMING.

First, EMISSIONS of Greenhouse Gases and Aerosols are what drive the additional ENERGY which is absorbed by the Planet.

I have to emphasize this:

EMISSIONS
is the most important element of
Climate Change.

Without accompanying cuts in global EMISSIONS, no near term conversion to ELECTRIC VEHICLES or expansion of SOLAR, WIND and NUCLEAR Energy, will in itself divert us from heating the Planet by 1.5, 2.0, 2.5, 3.0, 4.0 C, etc.. These are not emissions-related in themselves. You've got to see if emissions are also going down globally.

For the next several decades,
ONLY THE REDUCTION OF EMISSIONS
can change our trajectory towards these temperatures.
Of course, we have to accomplish this by moving to renewables, etc., but it's the global EMISSIONS we have to keep our eyes on.

[Some postulate that Carbon Removal and/or Geoengineering can help. Perhaps, but these are both speculative. In addition, geoengineering appears to have real risks, some enormous. For the next several decades - the period of most concern for avoiding these temperature increases - my statement stands.]

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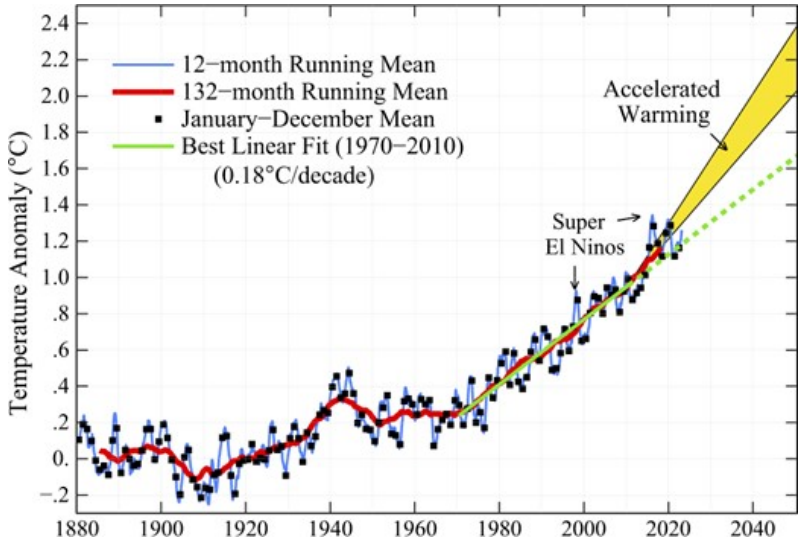
With that background, let's collect some FACTS from which to assess timeframes.

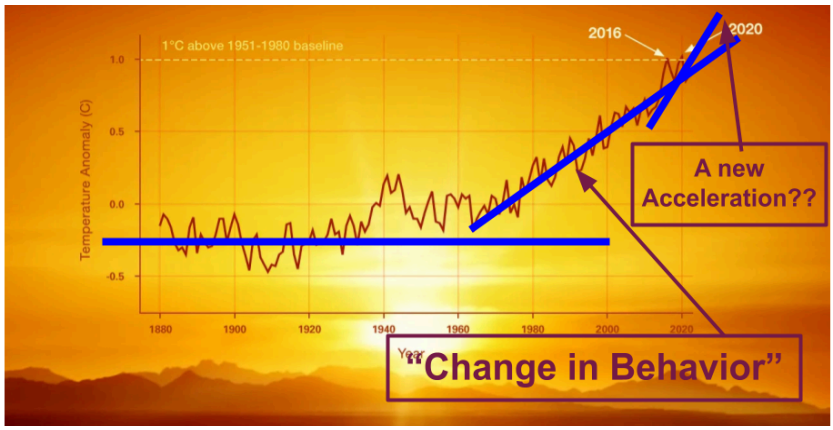
1. **FACT:** The Earth's Surface Temperature is steadily increasing, and may be accelerating, given new insights into paleo and Earth Energy Imbalance records.



https://academic.oup.com/oocc/article/3/1/kgad008/7335889 and https://www.columbia.edu/~mhs119/Temperature/

Note how this relates to CSSG-2.24 "Change of Behavior":

- the **linear behaviors** from 1970-2010 (the strong, blue diagonal line) and
- the **possible "acceleration"** of heating since (the "A new Acceleration? line).



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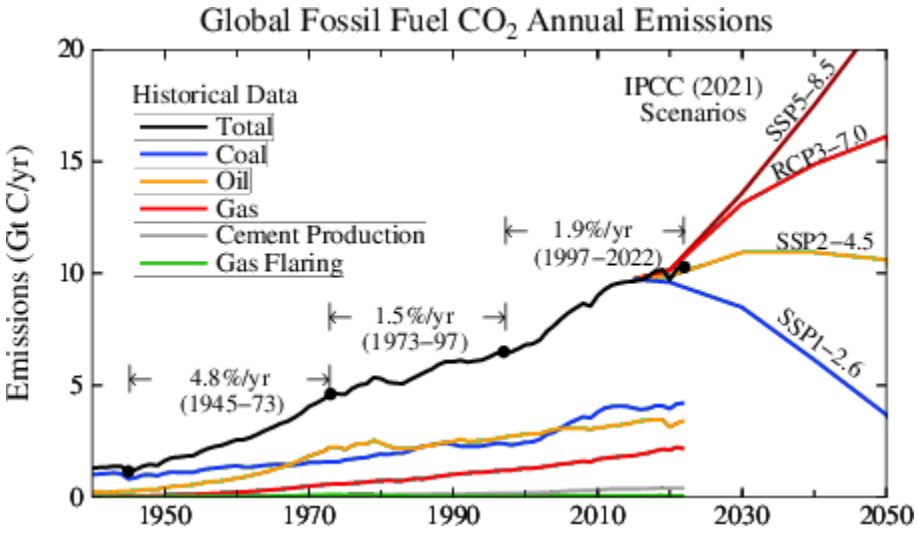
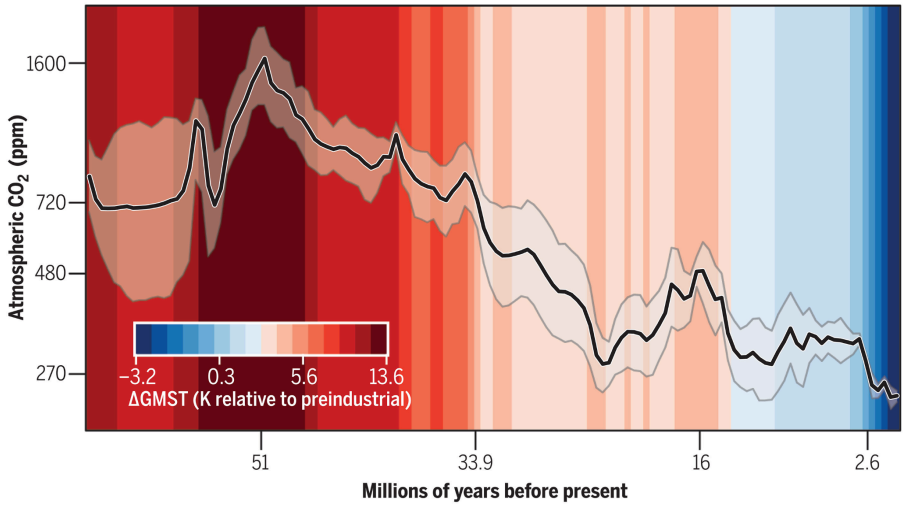
2. **FACT:** The atmospheric content of emissions is constantly going up, and will, until emissions go to **ZERO each year**. In addition, it has been accelerating since 1997.



https://www.columbia.edu/~mhs119/CO2Emissions/

To put this more into context, we have now reached the level of CO_2 (420+ ppm) in the atmosphere which has not been seen in millions of years, perhaps as many as 14 million years, when temperatures were on the order of 3+ ^{0}C, relative to preindustrial.



Community-vetted quantitative CO_2 record.
Paleo-CO_2 (including 95% credible intervals) is superimposed on the GMST trend over the past 66 million years. Age and CO_2 labels highlight notable climate extrema and transitions as described in the text. https://www.science.org/doi/10.1126/science.adi5177

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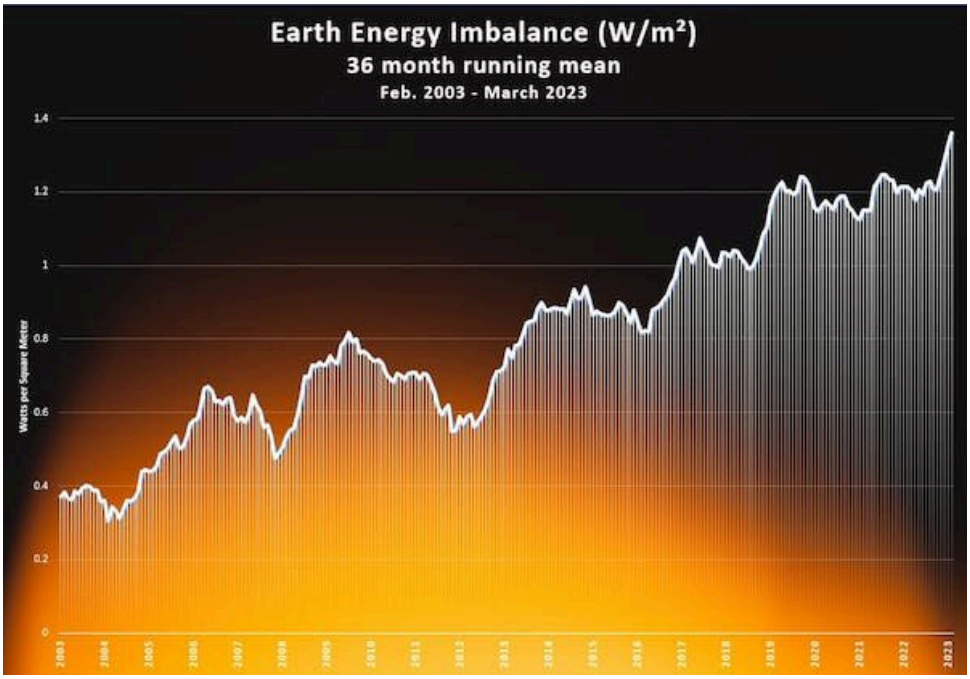
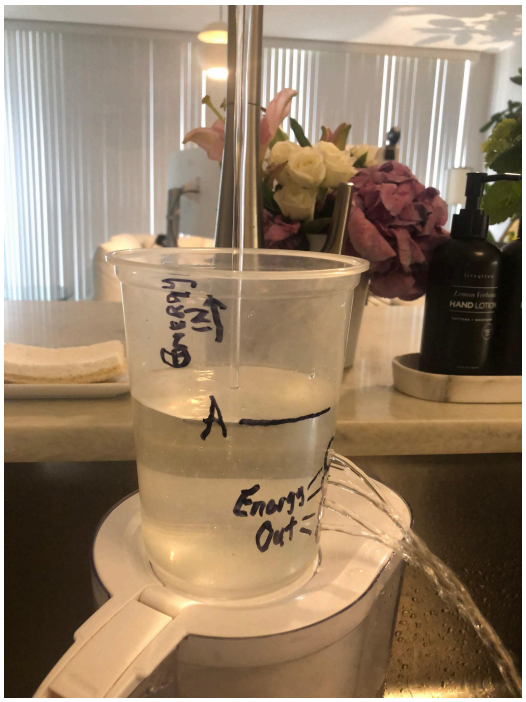
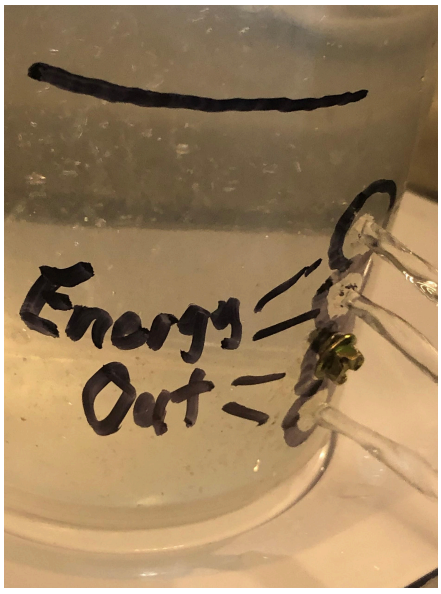
3. **FACT:** The Earth's Energy Imbalance (EEI) is constantly increasing, and may be accelerating. As remarked above, EMISSIONS of greenhouse gases and aerosols are what drive this imbalance.

4. 

https://phys.org/news/2023-06-global-average-sea-air-temperatures.html#google_vignette

Timing of Benchmark Climate Temperatures

Let's do an "Earth's Energy Imbalance" kitchen sink demo:

Here's the setup: • A steady water stream is incoming, simulating Incoming Energy • Four holes are drilled in the side so water can get out, simulating Outgoing Energy • A balanced condition, **A**, settles in, simulating the Earth's initial Equilibrium State. ENERGY IN = ENERGY OUT.	
At this point: • One of the holes letting water out is plugged up, simulating greenhouse gases now holding more energy and sending more down to the surface. Now, ENERGY IN is more than ENERGY OUT.	

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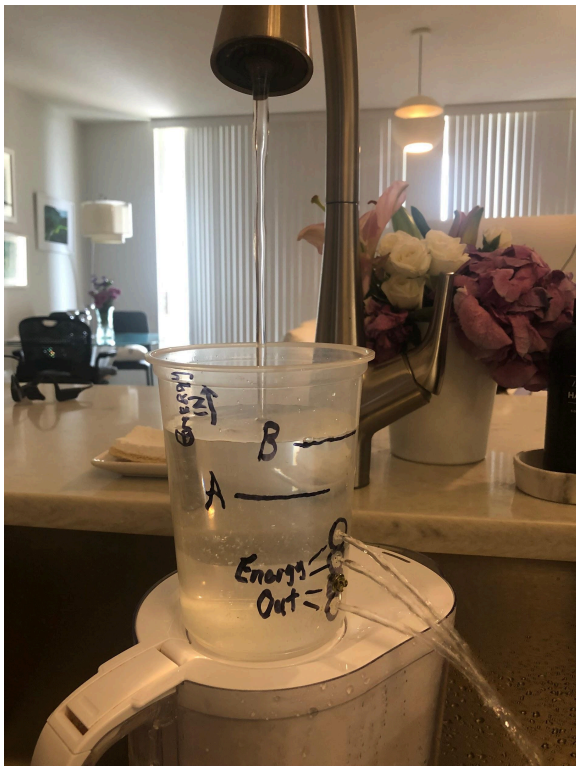
Now:

- A new equilibrium, **B**, is reached where the increased height of the water has increased the pressure up, pushing more water out of each of the three remaining holes.
- The amount of incoming and outgoing water HAS NOT CHANGED from when we started! But the conditions within the container have changed! There is a higher water pressure, simulating a HOTTER EARTH, which can give off more heat.
- Now, ENERGY IN = ENERGY OUT again.



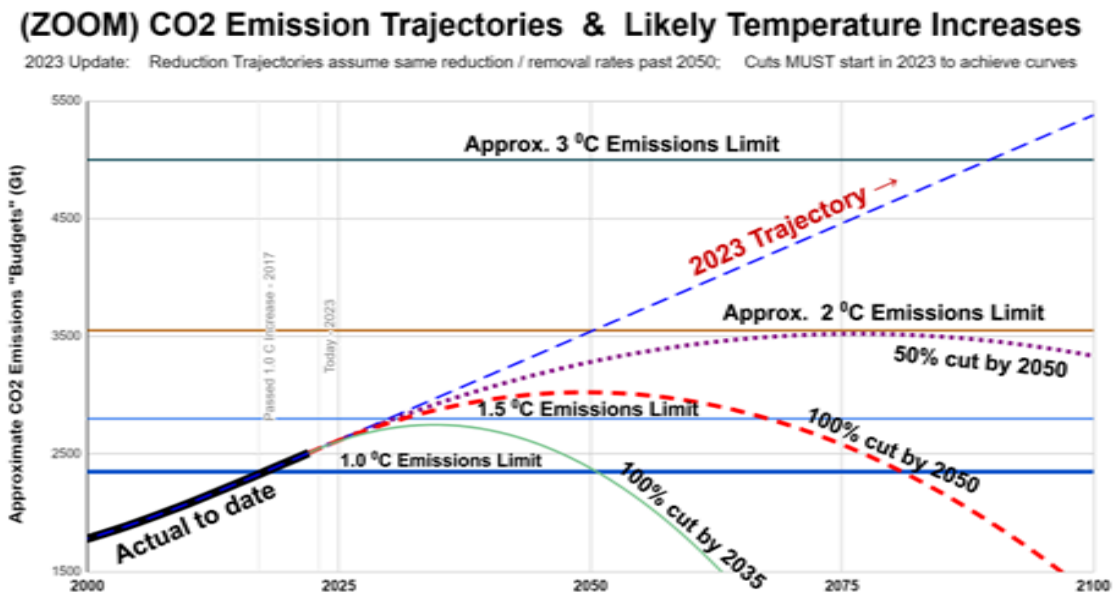
NOW WHAT CAN WE DISCERN ABOUT POTENTIAL TIMING OF BENCHMARK TEMPERATURES?

Timing of Benchmark Climate Temperatures

EMISSIONS Projection of Benchmark Temperature Timing

Let's look at the **EMISSIONS trajectory** we are actually on, in the context of the best physics models for Emissions Limits. Look at the "2023 Trajectory" line below:

- **1.0 C** was passed in 2017
- **1.5 C** is projected for about 2030 (remember these are climate projections, as opposed to this year's weather. So it takes several years' of averages to compare.
- **2.0 C** is projected for about 2050.
- **3.0 C** is projected for about 2088.



The above picture is based on **EMISSIONS**. But given fundamental uncertainties in how clouds will respond and how folks will work on reducing (lung-killing pollution) aerosols and other greenhouse gases on the way, we can expect the planet to behave a bit differently. Particularly, remember that millions of people die each year from pollution (aerosols) so they are aggressively being removed. The penalty is that these same aerosols have been reflecting incoming sunlight so are part of the reason we are not even hotter.

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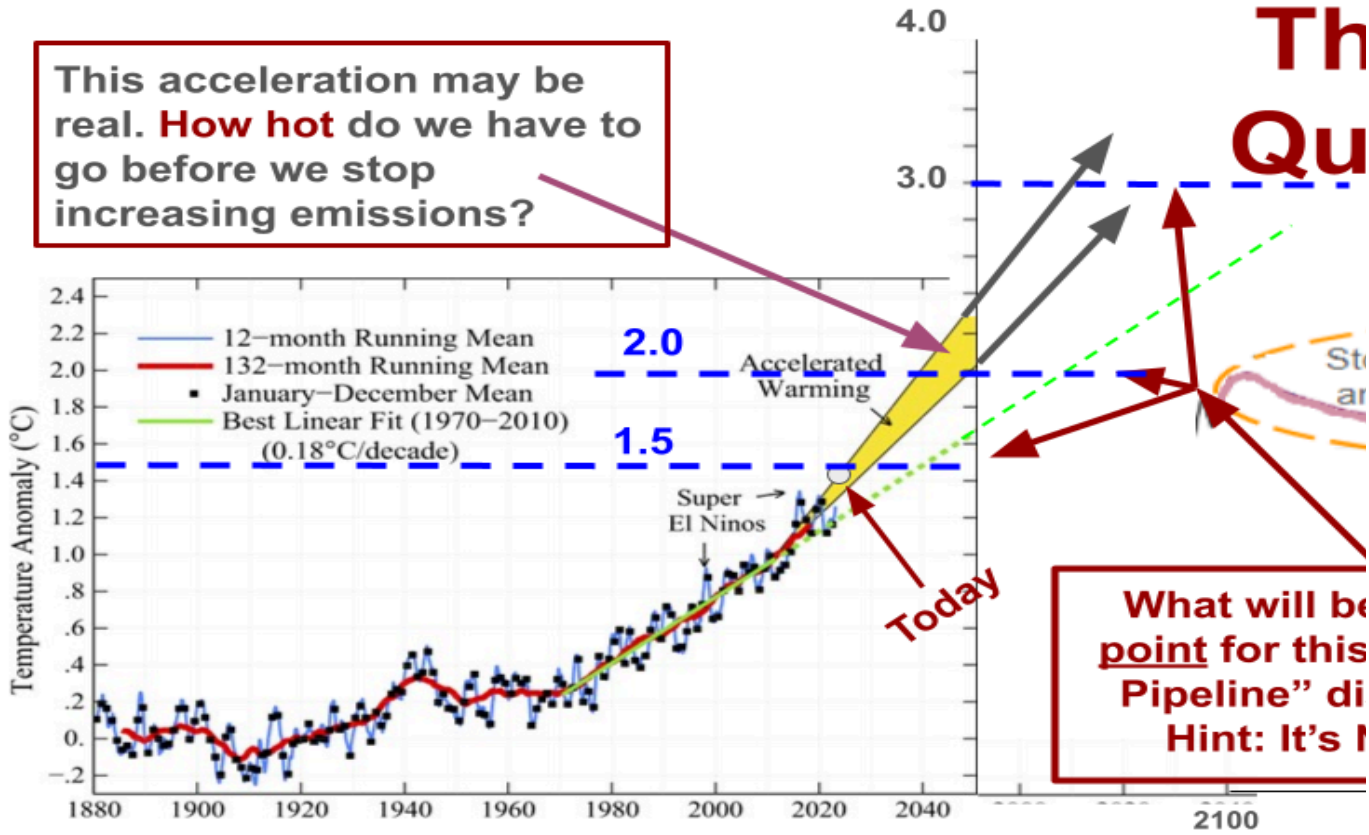
TEMPERATURE Projections of Benchmark Temperature Timing

Using CSSG-2.25 “In the Pipeline” supplemental chart, here chopped, we can look at these two cases:

1. projecting with a simple linear extension **from the actual data from 1970-2010** with the pale green dashed line below.
2. Projecting with recent analysis by Hansen et al. “Global Warming in the Pipeline” https://academic.oup.com/oocc/article/3/1/kgad008/7335889 with an extension **from the actual data since 2010** with a range shown in yellow **bordered by black arrows**.



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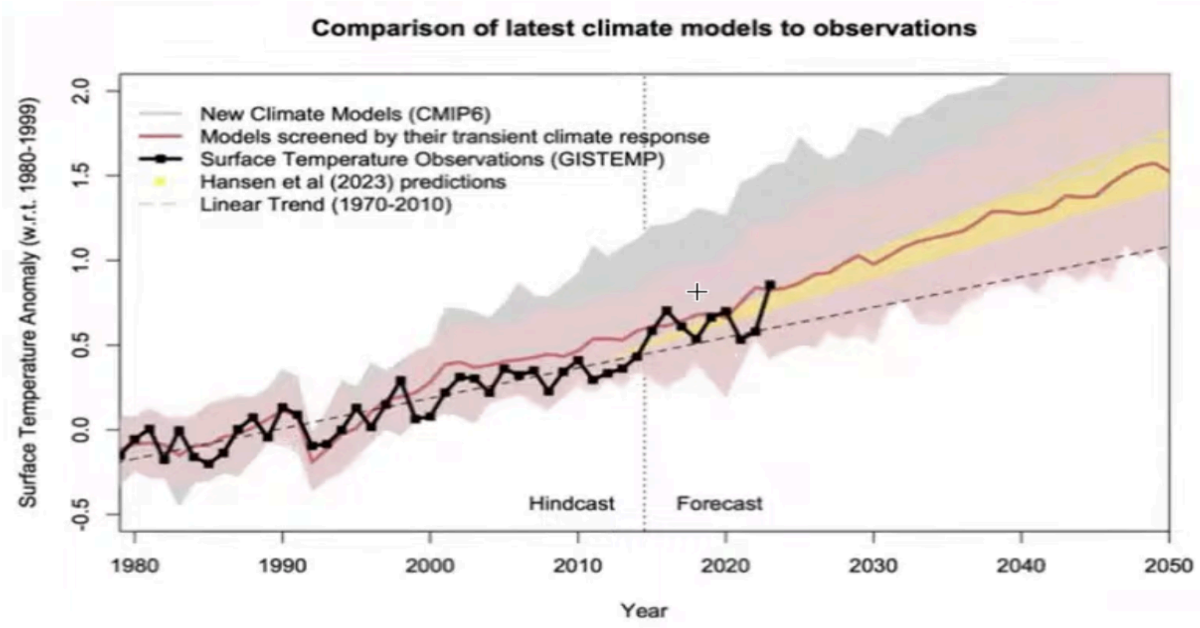
- 1.0 C was passed in 2017
- 1.5 C Today: the average global surface temperature for 2023 was 1.45 C above the industrial age. This doesn't equal climate, which looks at longer trends. The 10-year average looking backwards was 1.21 C. Given that the 10 hottest years were in the last 10 years, I will address Today as equivalent to the 1.5 C goal set by the Paris Agreement in 2015. https://www.columbia.edu/~mhs119/Temperature/Table_Ts.1880-2024vs1880-1920.txt Otherwise, around 2040.
- 2.0 C is projected for as early as 2040, if the recent evident "acceleration" of heating continues; otherwise around 2070.
- 3.0 C is projected for as early as 2070, if the recent "acceleration" of heating continues. Otherwise, around 2125.

Beyond the above **EMISSIONS** and **SURFACE TEMPERATURE** projections, there are a large number of computer **Global Climate Models** which have attempted to look into the future from incredibly complex system configurations. They have come up with an even broader range of possibilities for global **SURFACE TEMPERATURE** - we'll use the pink range, after 2024. The YELLOW band is from Hansen, as above ***[NOTE THESE TEMPS USE A 1980-1999 Baseline - not Industrial Age. I added about 0.7 C]:***



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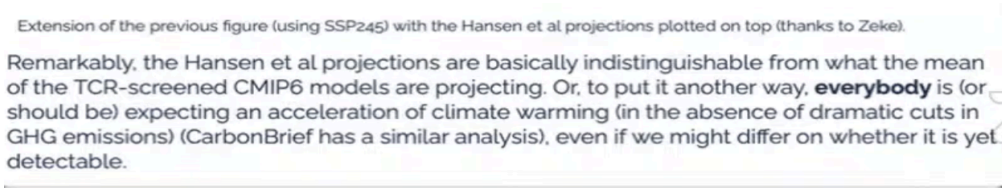

Extension of the previous figure (using SSP245) with the Hansen et al projections plotted on top (thanks to Zeke).

Remarkably, the Hansen et al projections are basically indistinguishable from what the mean of the TCR-screened CMIP6 models are projecting. Or, to put it another way, **everybody** is (or should be) expecting an acceleration of climate warming (in the absence of dramatic cuts in GHG emissions) (CarbonBrief has a similar analysis), even if we might differ on whether it is yet detectable.

SUMMARY

Global Surface Temperature increase since industrial revolution	Approximate Years we May Reach Average Global Surface Temperatures			
	Temperatures Based on the Trajectory of **EMISSIONS**	Based on simple linear projection of behavior 1970-2010	Based on Hansen projection of apparent **acceleration of TEMPERATURE increase** since 2010	Based on a broad spectrum of projections of Global Climate Models [the central red number is the red line averaging all improved models]
	The Earth's Energy Imbalance is caused by EMISSIONS	Temperature Changes are caused by how **"sensitive"** the Planet is to the Earth's Energy Imbalance. There is intense, ongoing study to estimate this Sensitivity.		
1.0 C	2017	2017	2017	2017
1.5 C	2030	2040	TODAY	2013-TODAY-2045
2.0 C	2050	2070	2040	2025-2045-2060
3.0 C	2088	2125	2070	2045-2070?-2100

This appears to me to be a very appropriate estimate of when we might be facing different warmings. It's well within the mid-range of projections.

Timing of Benchmark Climate Temperatures

1.5 C - NOW

2.0 C - Very Possibly by 2040 or thereabouts

3.0 C - Very Possibly by 2070 or thereabouts

These benchmark years are probably as good as I can hope for at this point.

As they say:

“Predictions are extremely difficult - especially when they are about the future”.