"In the Pipeline" - Part 2 - Zero Emissions

https://sciencing.com/how-does-polar-ice-melting-affect-the-environment-13400295.html

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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

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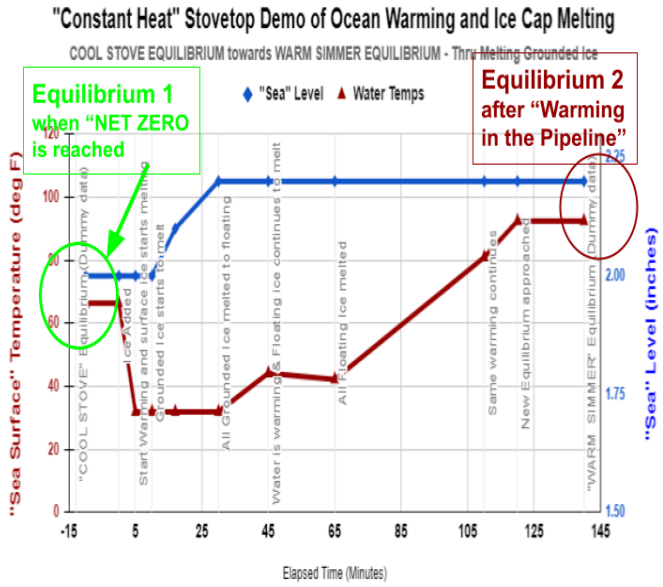
TWO WEEKS AGO, in CSSG-2.23 - Warming "In the Pipeline", I claimed that:

Global Warming doesn't stop when we cut emissions to ZERO.

Hoping to demonstrate this idea, I devised a stovetop demo to mimic Ocean Warming and Ice Cap Melting resulting in Sea Level Rise:



The concept was that Equilibrium 2 would be warmer than Equilibrium 1, after "Warming in the Pipeline".

This all seemed reasonable at the time, but it seems the real world is a bit more complicated (I didn't even notice I was ignoring the atmosphere)…

The question was asked: So what happens to the earth (as opposed to my stovetop demo) for this kind of scenario, where we go to ZERO EMISSIONS? Do we expect it to keep heating like the demo?

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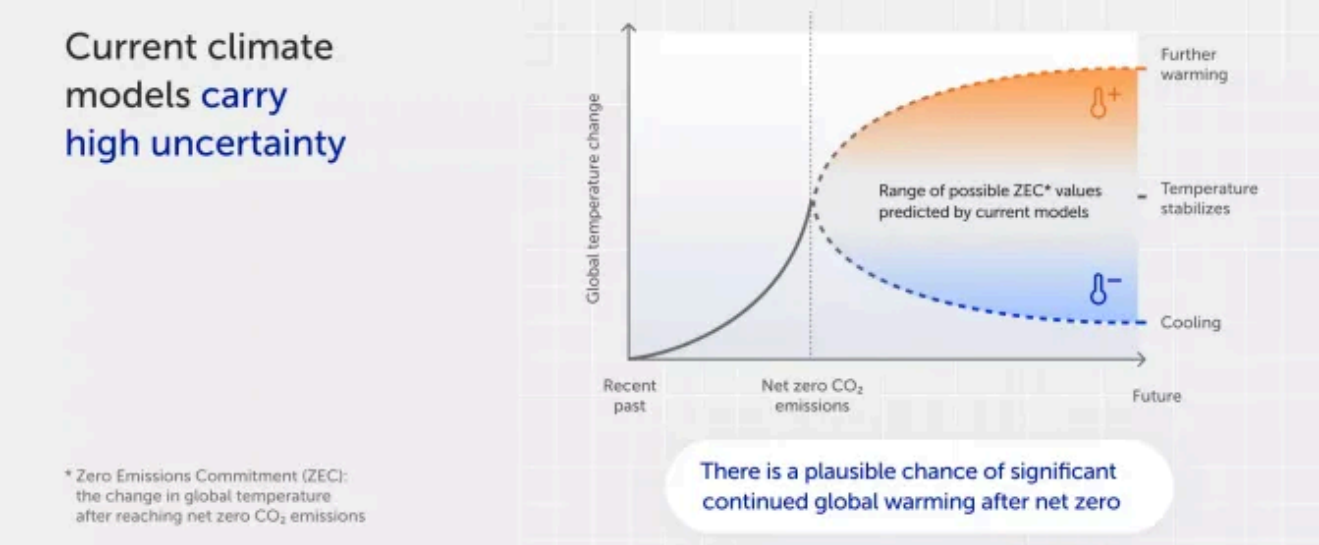
It turns out that answering that question is the subject of much study. One important distinction is how ZERO EMISSIONS are defined. Do we go to ZERO for all of these, or some mixture:

- **Carbon Dioxide (CO_2)**
- **Methane**
- **Nitrous Oxide**
- **Other trace Greenhouse Gasses (GHGs)**
- **Aerosols (which have a cooling effect, but are killing people)**

A summary Zero Emissions (CO_2 only) graphic was offered in
https://www.frontiersin.org/journals/science/article-hubs/global-warming-after-net-zero/explainer.



Look at what the graphic implies: **things could get hotter or cooler, or stay about the same, once we go to Zero CO_2 emissions.**

Also, notice that this graphic is ONLY about the atmosphere.

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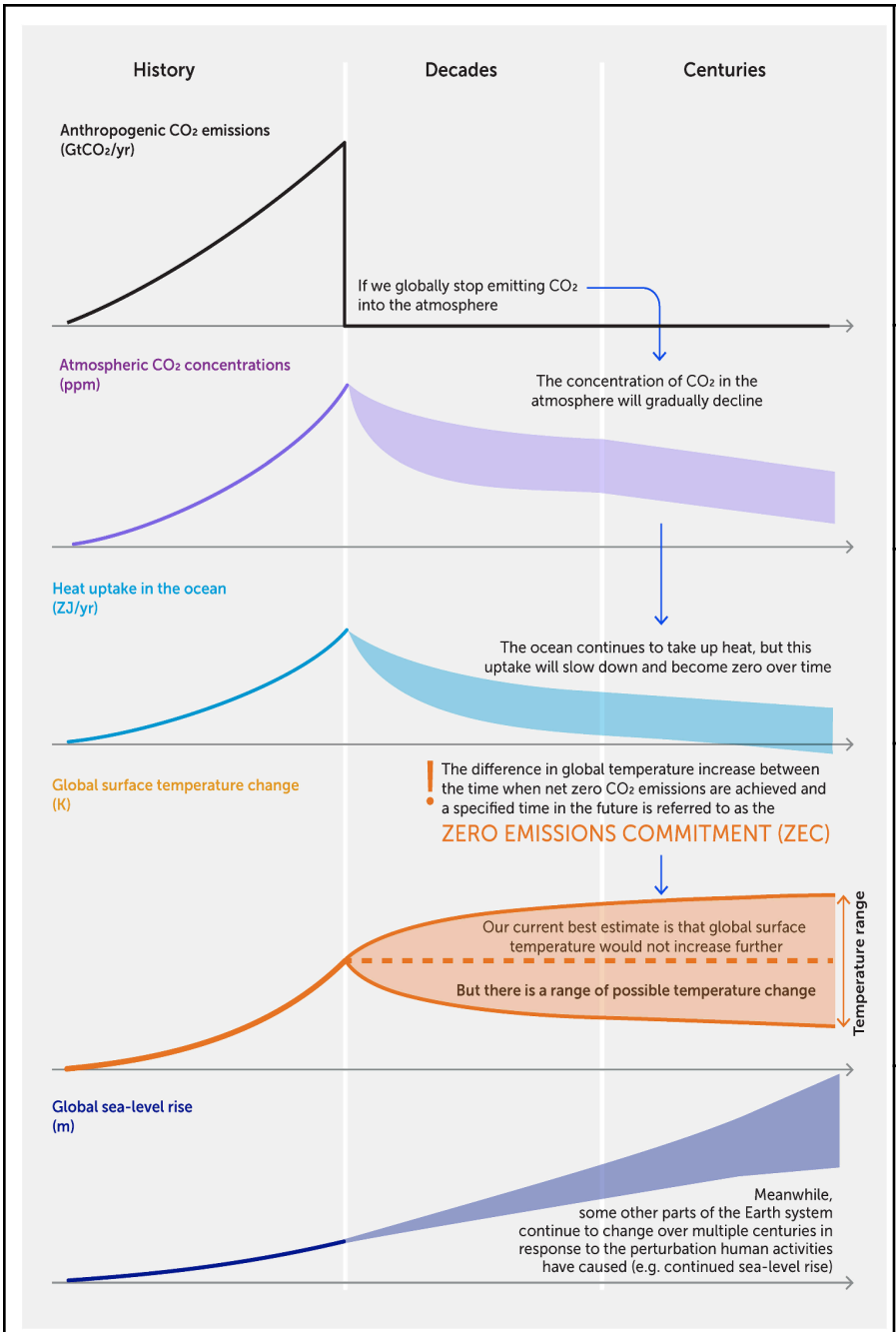
Let's take a slightly more detailed look at this situation (again, **for CO_2 only**):



1. The assumption is that **CO_2** emissions are sharply cut to ZERO.

2. Over decades to centuries, **CO_2** in the atmosphere gradually declines, primarily by absorption in the oceans. **But this means some heating would continue in the atmosphere with CO_2 . It's not ZERO.**.

3. But, the **ocean, which has been absorbing 90% of global warming all along, can still absorb more heat**, so it does…

4. The best guess is that the continued CO_2 heating of the atmosphere (2) would be **pretty much offset** by the heat taken out of the atmosphere by dumping into the oceans (3). So, it is estimated that **ZERO EMISSIONS would pretty much stop the atmosphere from getting hotter** (with some uncertainty on the chart.)

5. On the other hand, **Sea Level would continue to rise** from expansion from warming and from continued melting of the grounded ice, particularly in West Antarctica. Other systems would continue to be threatened, like the AMOK (see CSSG-2.17).

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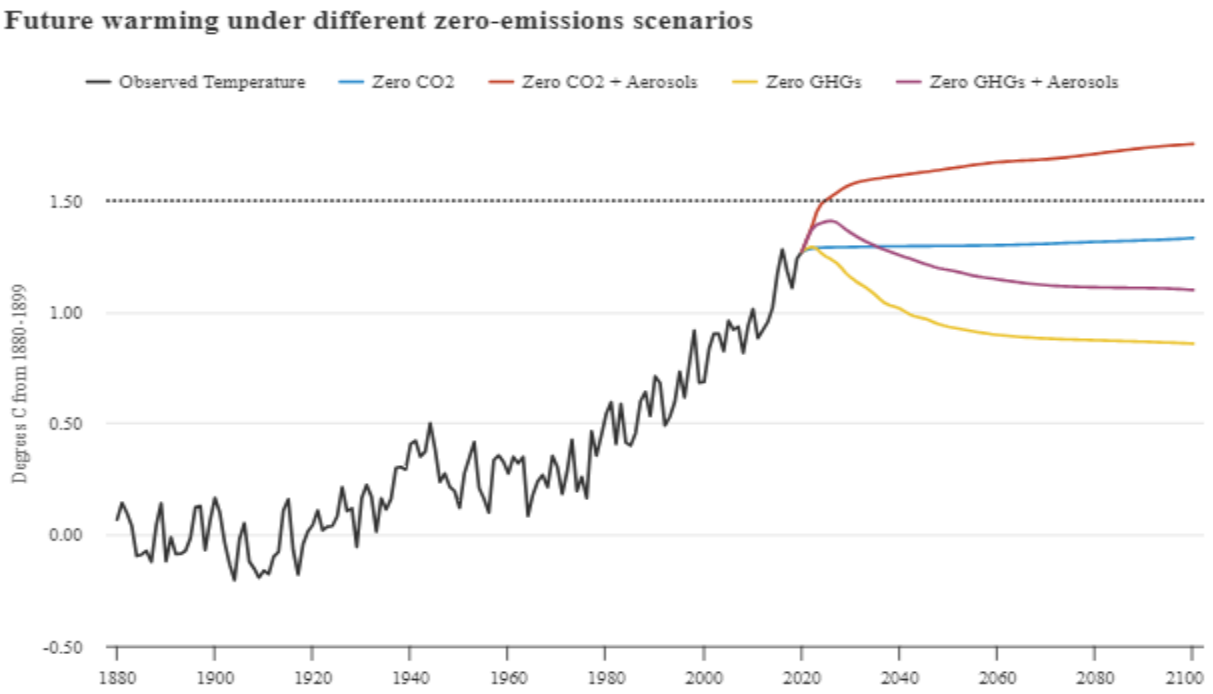
So Global Warming does continue if we go to ZERO CO_2 emissions, but the additional warming is mainly in the Ocean, not in the atmosphere.

If we consider **all of the GHGs and Aerosols**, we get a spread of possible outcomes, as depicted in this graphic (a more detailed discussion can be found in the "Supplemental Materials" at the end of this study.

Basically, it suggests that strongly moving to cut GHGs and aerosols may keep the atmosphere near its temperature as of when a full ZERO is achieved.

So far, no one imagines that ZERO on any of these fronts will be achieved anytime soon. Therefore, the starting point for the zero-zone (my term!) will keep moving upwards…



https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached/

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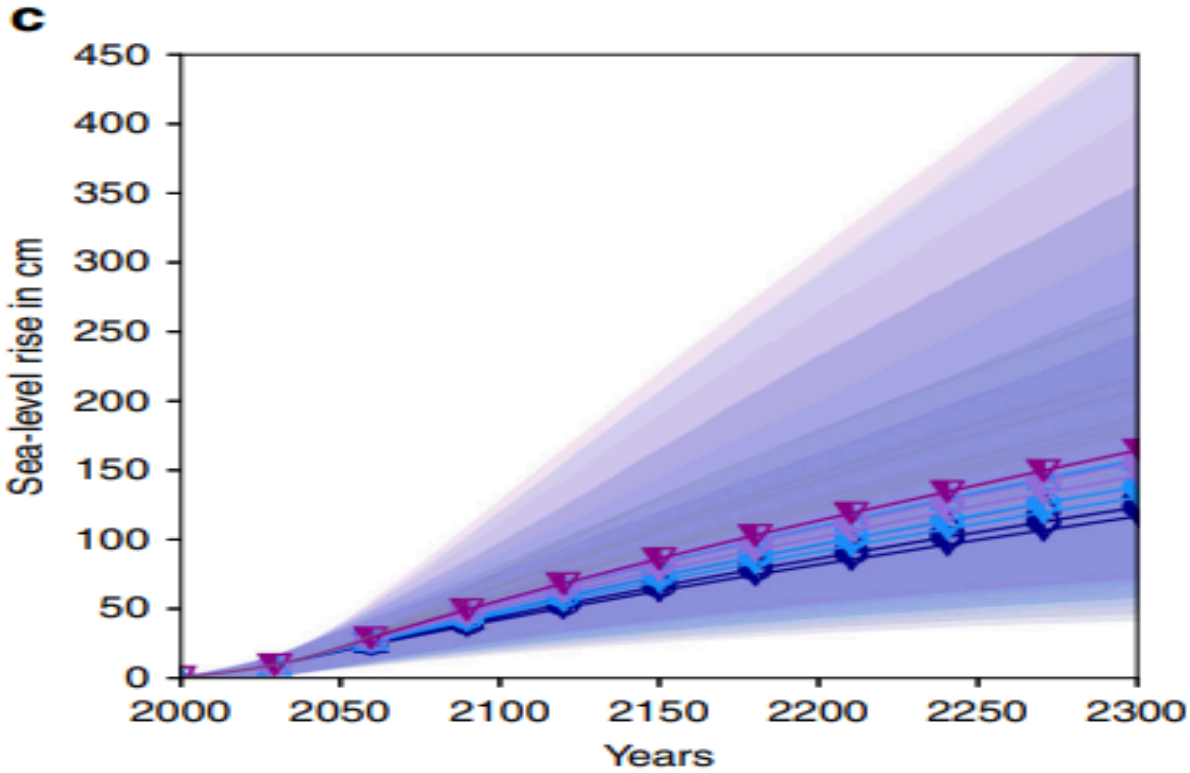
Finally, what can be said about SEA LEVEL RISE, since most of the warming after ZERO is achieved will be shunted to the OCEANS?

A helpful analysis of this question was offered in:
https://www.researchgate.net/figure/Response-of-the-sea-level-contributors-to-net-zero-CO2-scenarios-Time-series-of-the_fig2_323291634

Again, more details are shown in the Supplemental Materials to this Study, but here are some take-aways:

- This chart, (c) below, reflected pretty constant atmospheric temperatures after going to Zero CO_2. From materials above, I think we can get a similar result by going to ZERO GHGs and ZERO Aerosols, because of generally offsetting effects.
- The chart assumes achieving ZERO emissions by around 2050 or so, which we don't seem to be on track for. If we don't make it, the sea level rise shown here would be too low.



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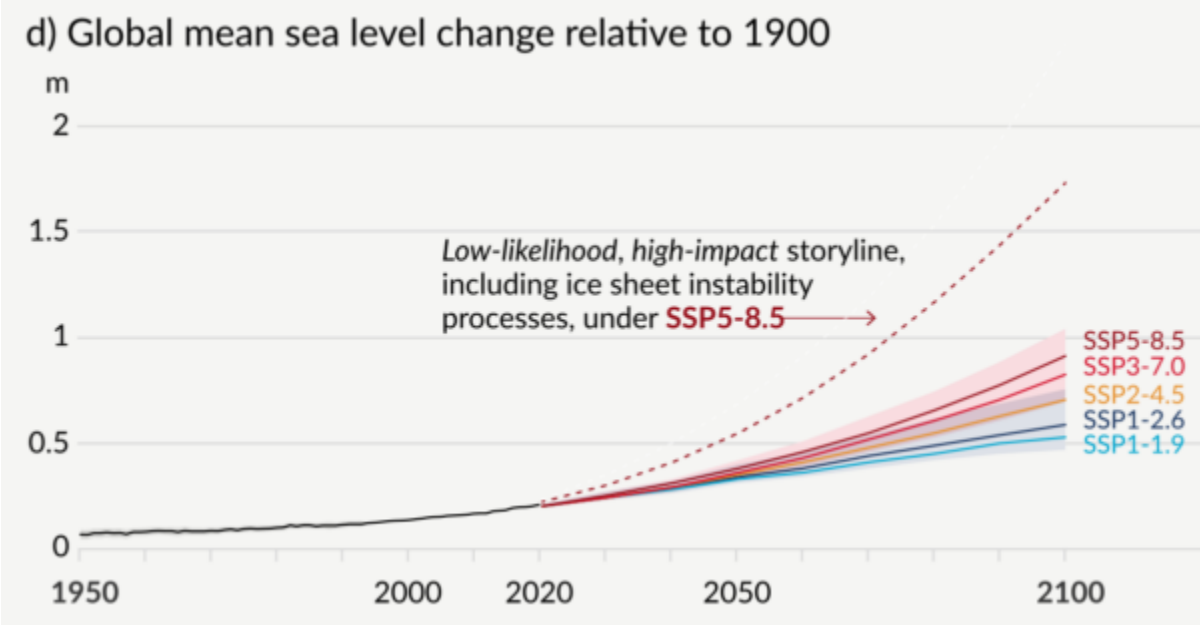
The above does not take into account the possibility of hitting an ice sheet collapse tipping point. Here are graphics from the IPCC on that matter



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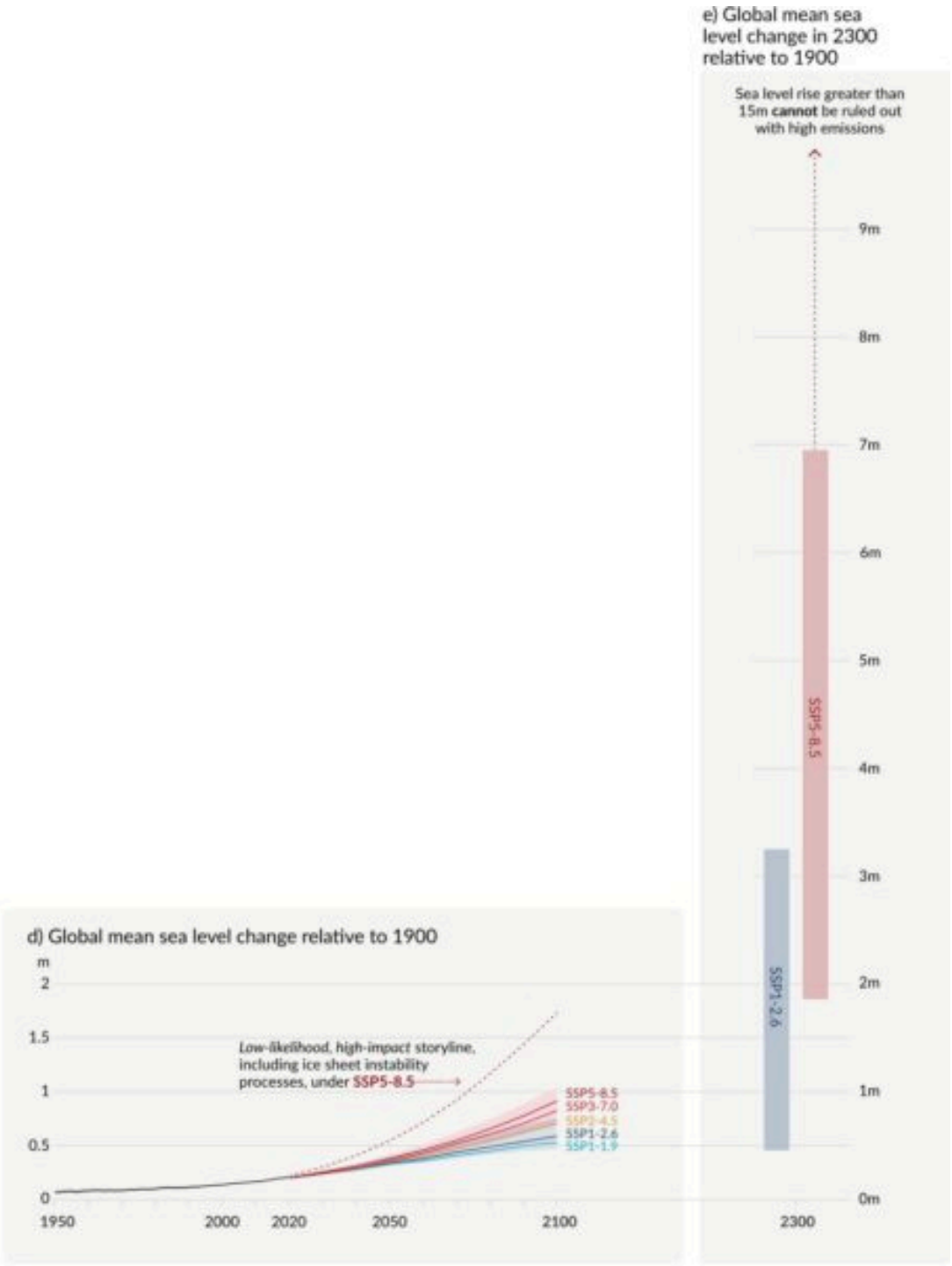

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PUNCHLINES:

- The Aerosols above are the major source of air pollution on the globe and (while not discussed here) cause millions of deaths each year - so there are efforts worldwide to eliminate them.

- Going to ZERO GHG EMISSIONS in the atmosphere could help cool the planet. However, such actions will likely be coupled with needed major cuts in Aerosols - which will increase warming in the atmosphere.

- It looks like the atmospheric temperature would likely stay within ±0.5 ^{0}C of the global temperature at the time ZERO is achieved.

- In all scenarios where CO_2 in the atmosphere stays above perhaps 350 parts per million (this value was not discussed here - it's now 428 ppm), SEA LEVELS will continue to rise from expansion from warming and melting of grounded ice.

- Every ±0.1 ^{0}C MATTERS to the planet (again, not discussed here), so getting to and through this Zero-Zone matters.

- The biggest question remains: How soon can we cut emissions? The charts above assume ZERO occurs NOW. What temperatures will we reach before stopping the ongoing rise?

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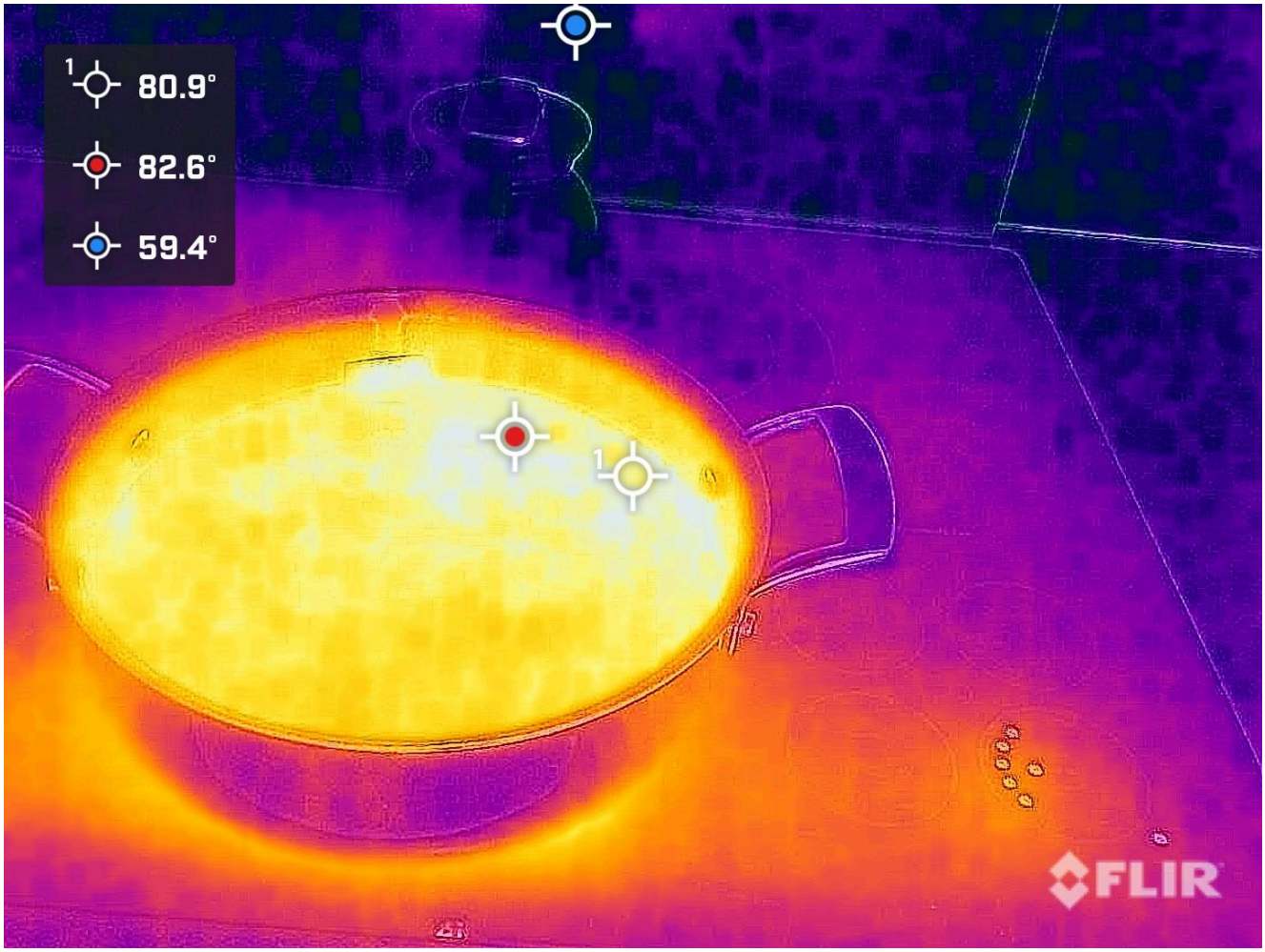

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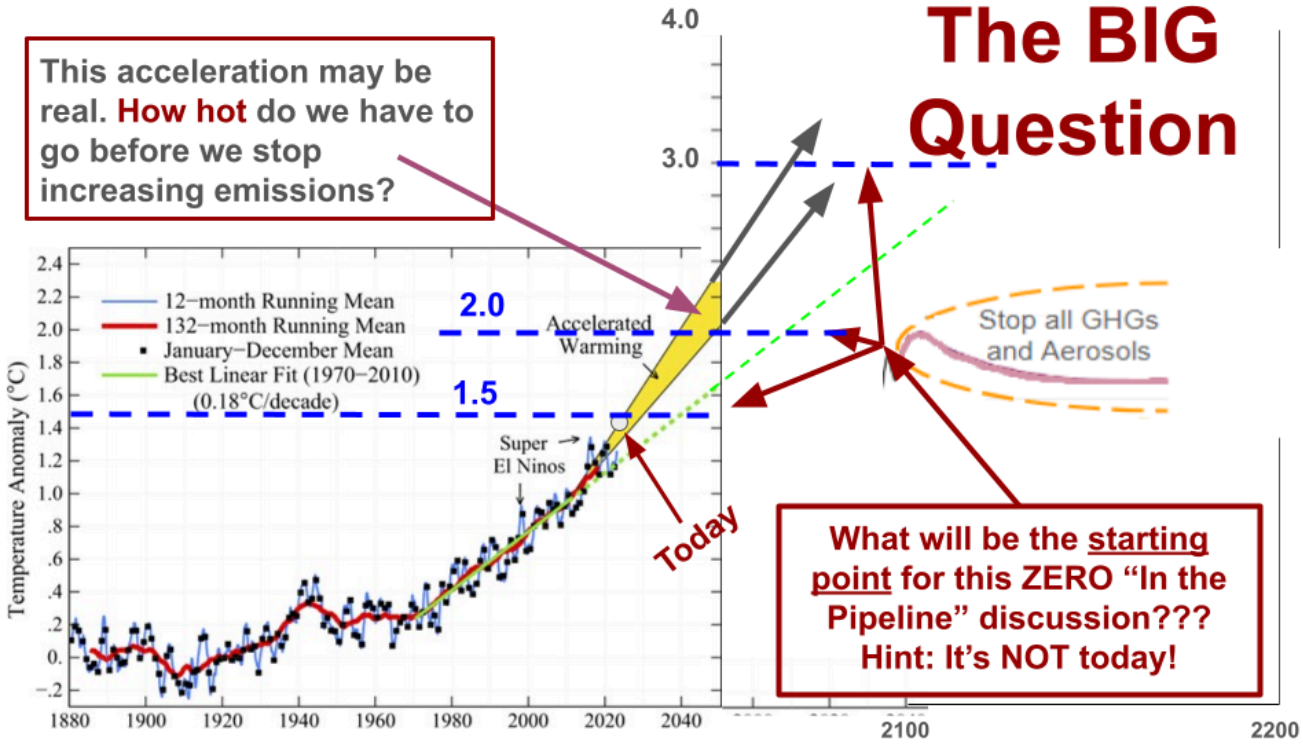
SUPPLEMENTAL MATERIAL:



Let's look briefly (DON'T SWEAT THE DETAILS!) at other components in the atmosphere which can have an effect: methane and other GHGs, and aerosols. This is discussed in more detail in: https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached/

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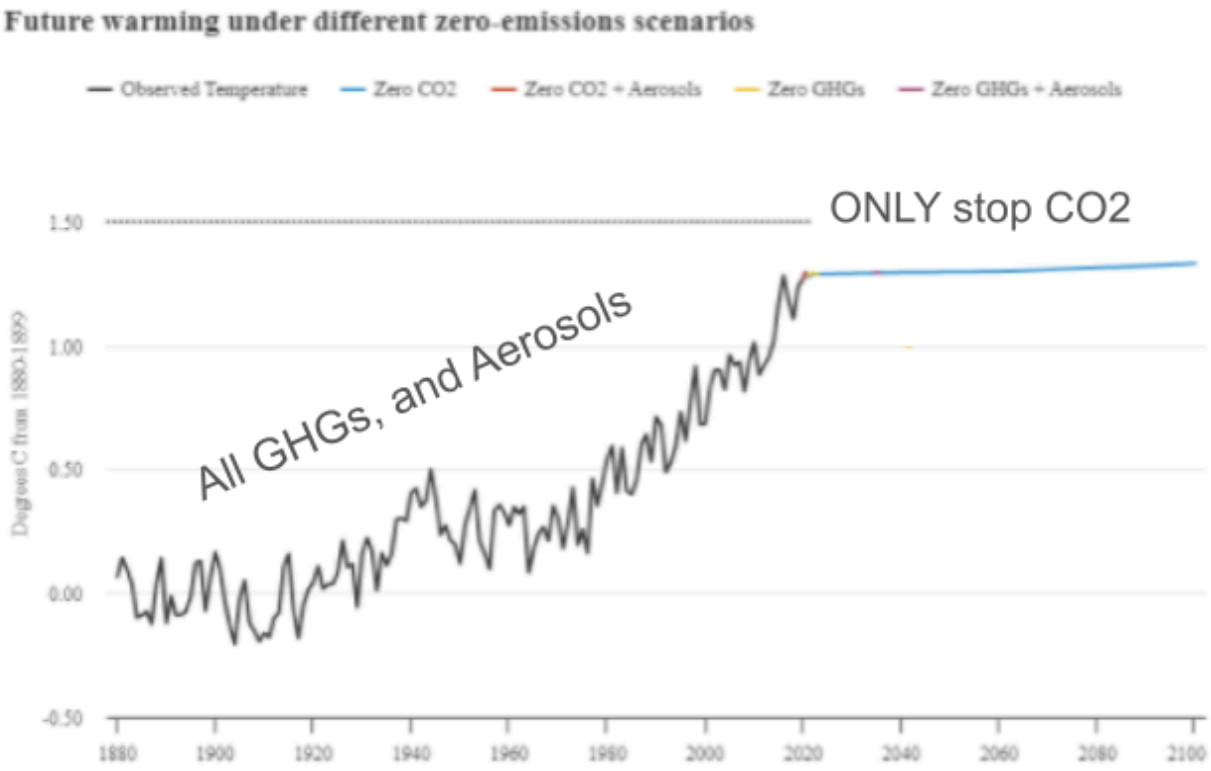
1. **As we saw earlier, suddenly stopping CO_2 (only) emissions is likely to stabilize the atmospheric temperature where it is when the cut is made.**



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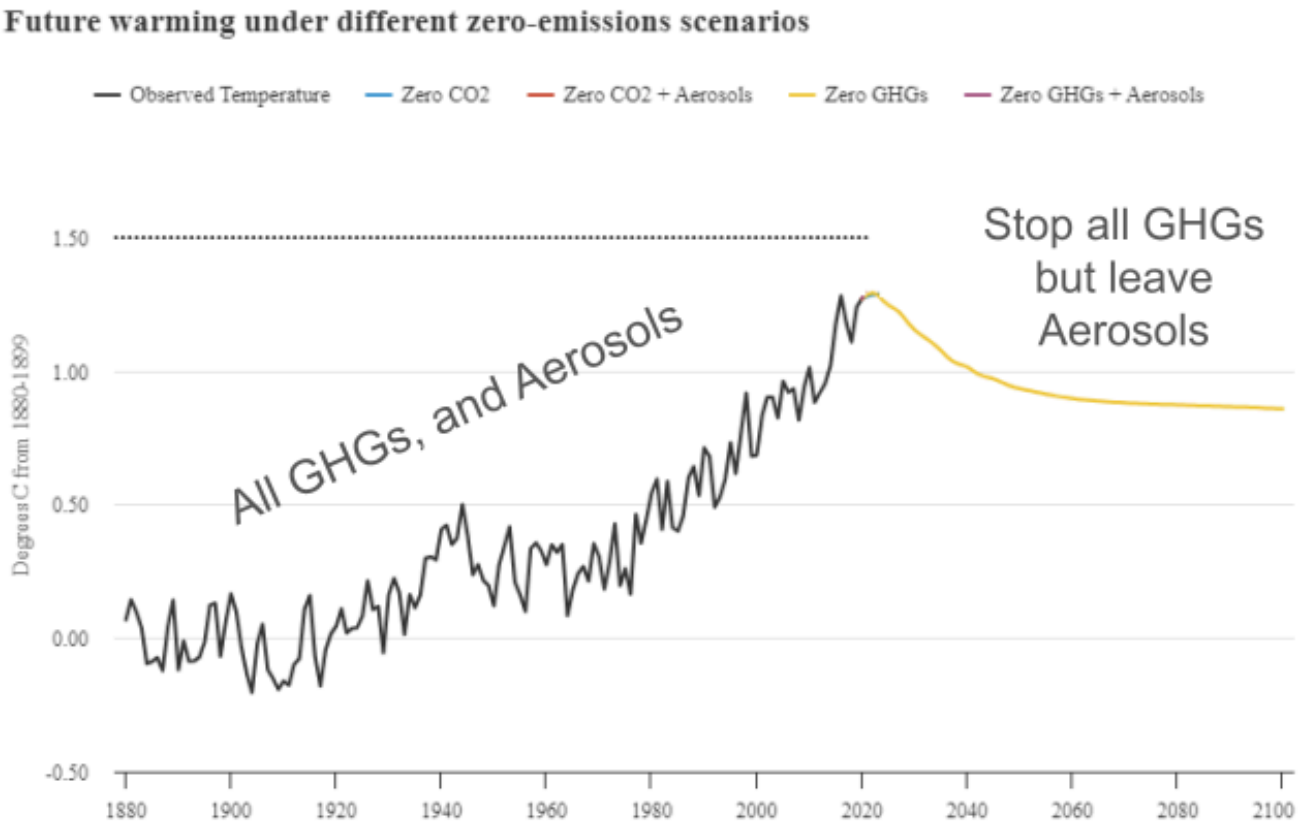
2. **If we take this further, and eliminate <u>all</u> GHG emissions at the same time (CO_2, methane, nitrous oxide, etc,) but leave the aerosols, the <u>atmosphere</u> is likely to cool a bit.**

   What's happening is methane, etc. are powerful, but pretty short lived. So they have a significant impact immediately as they diminish. Meanwhile the aerosols continue their cooling action, so are helping out.



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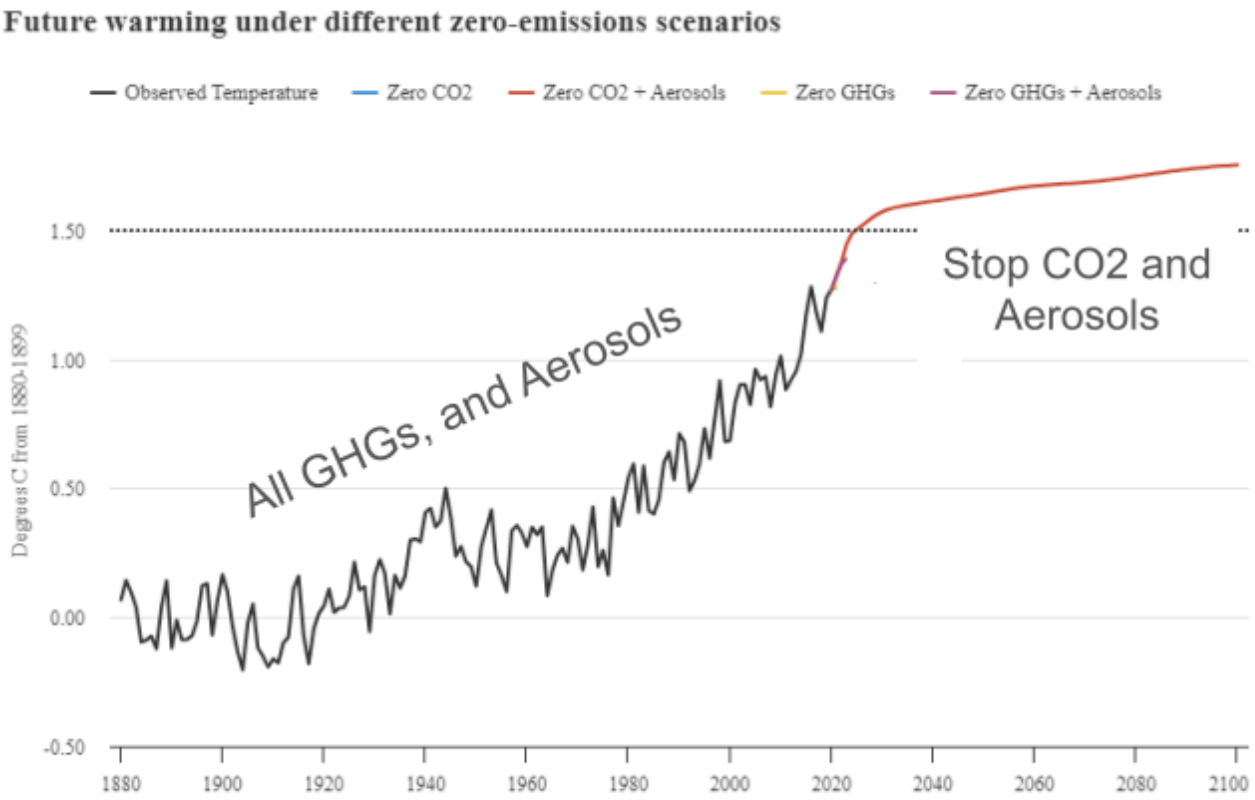
3. **Aerosols, as we've discussed, have a cooling effect on the atmosphere because they and the clouds they stimulate reflect sunlight back out to space before it can heat anything.**

   This means these pollutants (mostly byproducts of the combustions that gave us the warming GHGs in the first place) have been masking the problem. So this chart is a modification of Chart 1, above, where only CO2 was stopped. There is **STRONG HEATING, even with the CO2 stopping**.



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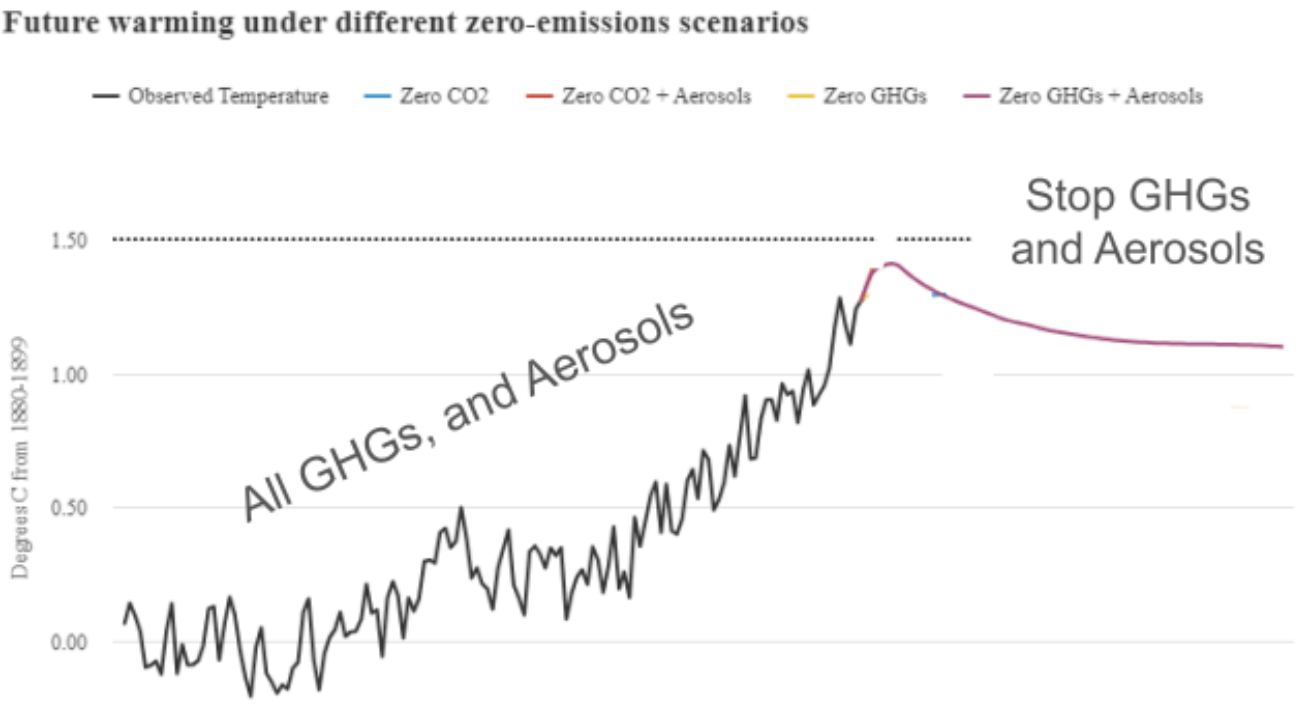
4. **On the other hand, if we can stop all GHGs and aerosols at the same time, we may be able to effect some net cooling of the atmosphere, or at least not make it worse.**



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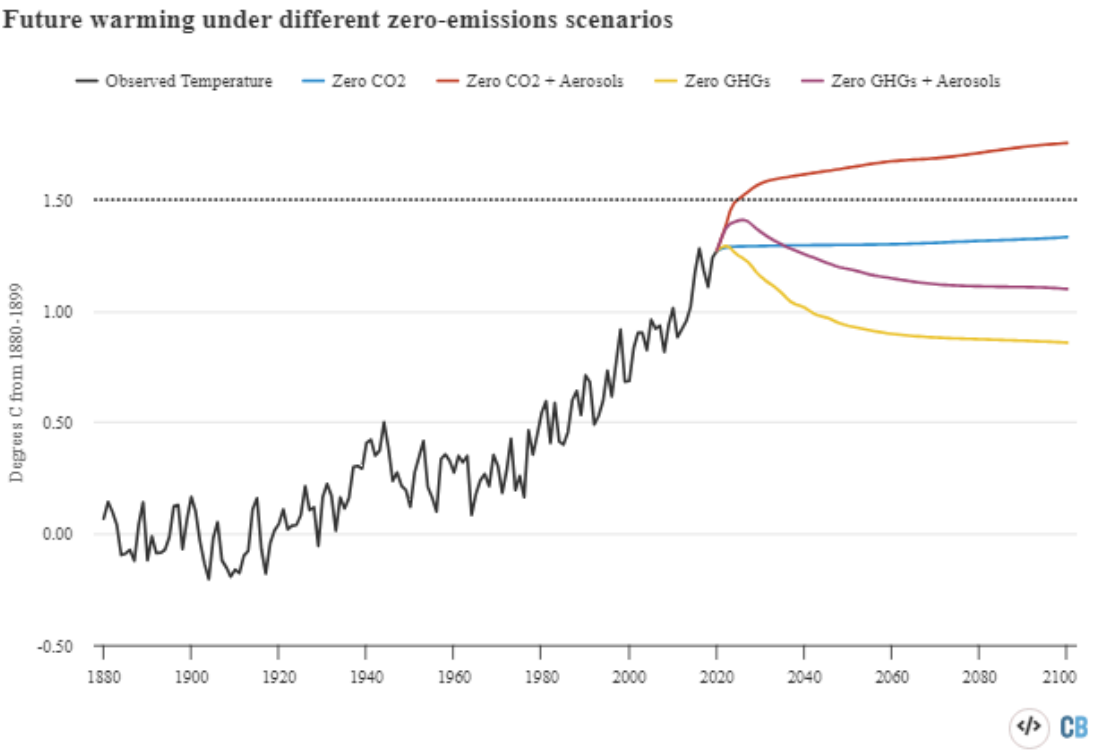
5. **Here's the chart pulling all the above curves together. Basically, it suggests that strongly moving to cut GHGs and aerosols may keep the <u>atmosphere</u> near its temperature as of when a full ZERO is achieved.**

   So far, no one imagines that ZERO on any of these fronts will be achieved anytime soon. Therefore, the starting point for the zero-zone (my term!) will keep moving upwards…



Projected global surface temperature changes under zero CO2 emissions (blue line), zero CO2 and aerosol emissions (red), zero GHG emissions (yellow) and zero GHG and aerosol emissions (purple). Chart by Carbon Brief using Highcharts, adapted from Figure 1.5 in the IPCC SR15. Historical warming values (black) and combination with model simulations are estimated using the methods described in the first figure.

https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached/

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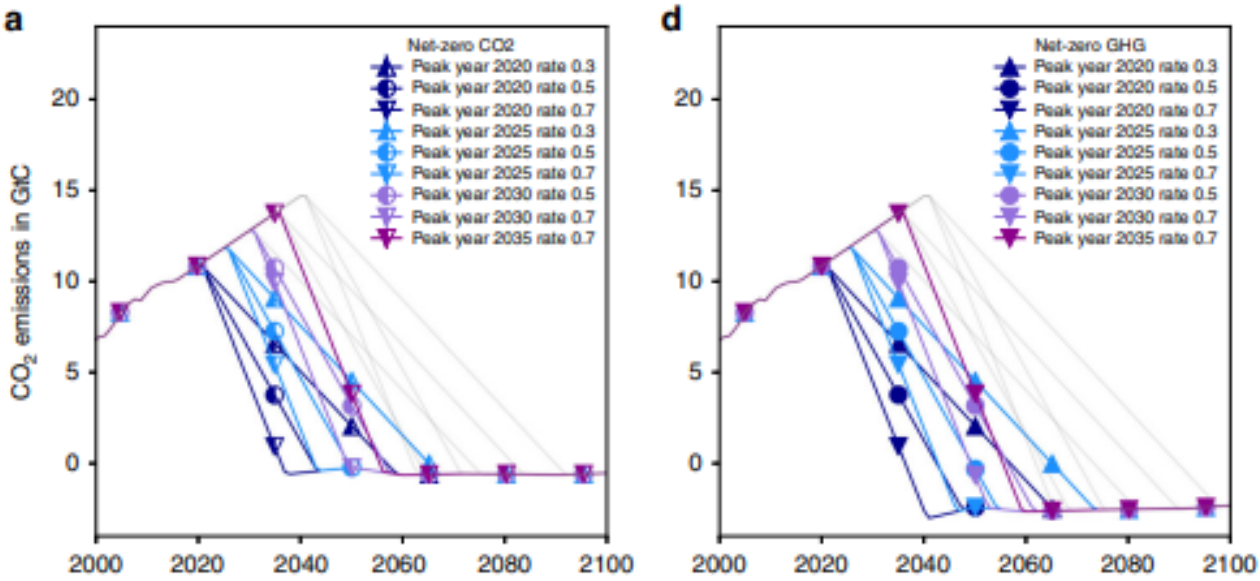
6. **Finally, what can be said about SEA LEVEL RISE, since most of the warming after ZERO is achieved will be shunted to the OCEANS? A helpful analysis of this question was offered in:**
   https://www.researchgate.net/figure/Response-of-the-sea-level-contributors-to-net-zero-CO2-scenarios-Time-series-of-the_fig2_323291634

   PLEASE DON'T SWEAT THE DETAILS! Just note the two emissions assumptions: **a = CO_2** and **d = all GHGs.** These are going to Net-Zero, with emissions peaking at various years from 2020 through 2035. **These assumptions**, coupled with the exclusion of Aerosols from this discussion, likely means these **are too optimistic**.



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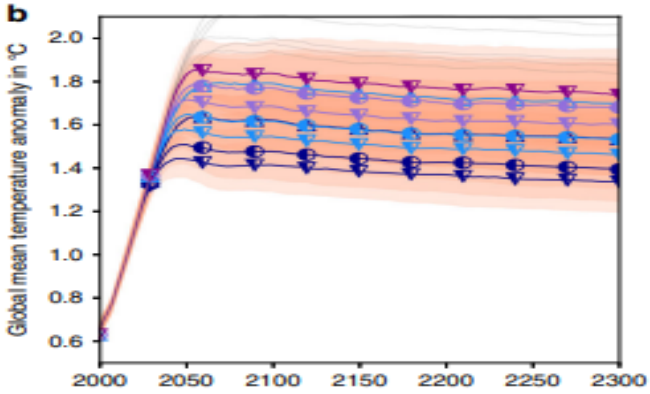
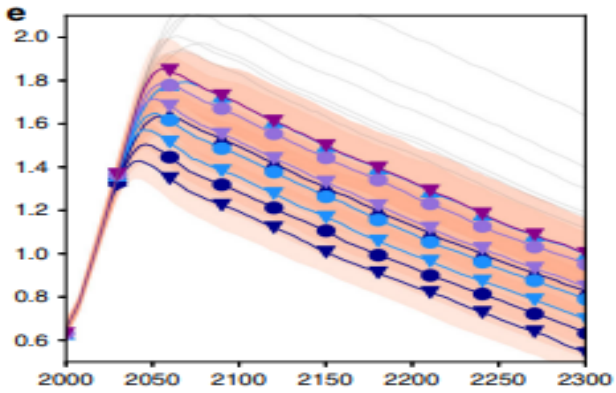
These two emission assumptions yielded the following atmospheric temperatures over the next centuries to 2300. (You can see that the analysis was done in 2018, hoping to support the Paris agreement goals of 1.5 and 2.0 ^{0}C - now both unlikely to be achieved.)

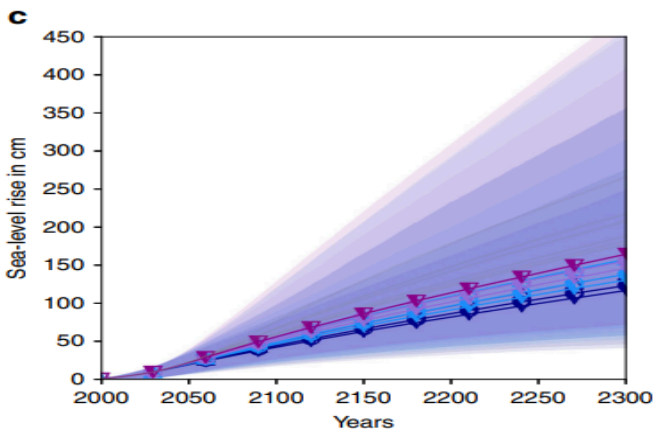
ZERO CO_2

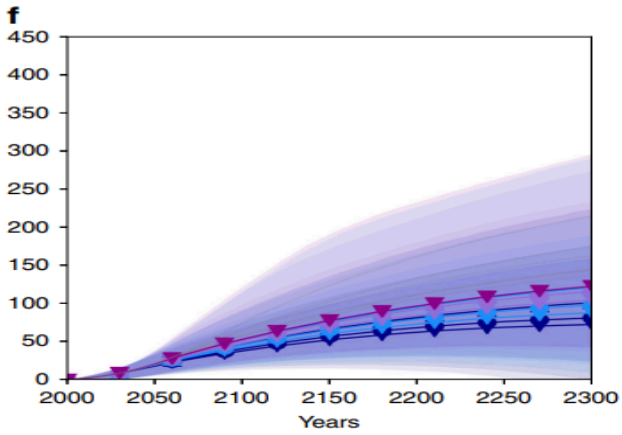


ZERO GHGs



Note the strong improvement by getting rid of all GHGs vs. just CO_2. Again, I assume you would do all GHGs; however, you would also eliminate aerosols, so the curve would again be more like (b).





My assumption is that SEA LEVEL RISE just keeps on going in the mode of (c), because atmospheric warming is more likely to level off like (b), because of aerosol removal. The shading indicates 90% likelihood of being in the shading, so it's a pretty broad range.

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