Our goal here is to arm those in outreach with just enough data to answer some of the more common objections to anthropogenic global warming, taking CO2 as a proxy for well-mixed greenhouse gases (GHGs).

The blue curve in Figure 1 plots the combined mass of water vapor (assumed constant at 12.9 exagrams\(^1\)) and CO2, for the 1.68 centuries 1851-2019. Trends in global mean land temperature in °F are shown in red.

Both have a hockey-stick shape whose shaft lies in the first three-quarters (1.26 centuries) and whose blade occupies the remaining 0.42 centuries. Columns 1-7 of Table 1 quantify the butt end (1851), rise and centennial rate of the shaft, the heel (1977), rise and centennial rate of the blade, and the toe (2019) of the hockey stick. The table adds a row at the top for cumulative CO2 emissions, also in exagrams.

In preindustrial times the distribution of CO2 between Earth's surface and atmosphere was in reasonable equilibrium. Whenever such an equilibrium is disturbed by increasing the gas in one of the regions, it typically rebalances itself by moving a fraction of the excess gas to the other region. The two green columns in Table 1 nicely illustrate this behavior: in each column a significant fraction of the CO2 emissions has evidently been drawn down. Other explanations that have been proposed for where these rising atmospheric GHGs might be coming from lack comparably compelling corroborative detail.

In 1896 Arrhenius predicted that rising atmospheric CO2 would warm the planet. The first red row in Table 1 shows CO2 rising 1.40/0.29 = 4.8 faster during the blade than during the shaft, so if Arrhenius were right we should see temperature rising faster too. And indeed we do, namely 2.04/0.73 = 2.8 times faster.

Prior to the 19th century GHGs averaged about 15 Eg, a level that kept Earth’s surface about 60 °F above what it would be without them, or 4 °F per Eg. The blade’s rise of 0.59 Eg could therefore be expected to raise the temperature by about 2.4 °F at equilibrium. The observed rise of 2.04 °F represents the lower transient (immediate) climate response, modulo our tacit assumption that these two triatomic gases have similar global warming potentials, both much lower than five-atom methane.


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\(^1\) 1 Eg (exagram) = 10\(^{18}\) grams or a thousand gigatonnes.