



# Comment on “Extreme Level of CO<sub>2</sub> Accumulation Into the Atmosphere due to the Unequal Global Carbon Emission and Sequestration” by M. F. Hossain

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**Abstract** Rising atmospheric concentrations of carbon dioxide (CO<sub>2</sub>) and other greenhouse gases are driving modern climate change and, therefore, are having substantial and sustained impacts on natural ecosystems and human populations. In a recent article in this journal, M. F. Hossain (2022. *Water, Air, and Soil Pollution*. 233:105) calculated how anthropogenic activity has perturbed the global carbon cycle, forecast future increases in atmospheric CO<sub>2</sub> concentrations, and discussed possible health consequences from rising CO<sub>2</sub> levels. However, Hossain’s article gave an inaccurate representation of how human actions have altered the global carbon cycle. He substantially underestimated the magnitude of anthropogenic disturbances in terms of CO<sub>2</sub> emissions from fossil fuel combustion and land use change and also underestimated the role of land and ocean processes in removing some of the emitted CO<sub>2</sub> from the atmosphere. At the same time, he overestimated the rate at which atmospheric CO<sub>2</sub> levels are increasing, resulting in a highly improbable forecast for atmospheric CO<sub>2</sub> concentrations later in this century. He also exaggerated the health impacts from exposure to those CO<sub>2</sub> levels as being severe and deadly, when our current understanding suggests that the

direct effects are uncertain but likely minor. Because each of the major components of Hossain (2022) contains substantial and fundamental flaws, I warn readers to be skeptical before incorporating its findings into their understanding of carbon cycling, climate change, and human health.

**Keywords** Global Carbon Cycle · Climate Change · Carbon Dioxide · Human Health

## 1 Introduction

Anthropogenic perturbations to the global carbon cycle have been studied and quantified for more than 80 years, beginning in the 1930s (Callendar, 1938) and extending through today’s annual updates to the global carbon budget (e.g., Friedlingstein et al., 2019, 2020, 2022). Collectively, this research has demonstrated that atmospheric concentrations of the greenhouse gas carbon dioxide (CO<sub>2</sub>) have risen from ~280 ppm before the Industrial Revolution to roughly 420 ppm today (Jul 2022), an increase that is due to anthropogenic fossil fuel combustion and land use change (Ciais et al., 2013). The rise in CO<sub>2</sub> concentrations is the single largest factor affecting global radiative forcing (Myhre et al., 2013) and has contributed to widespread climate changes including warming of the atmosphere and ocean, changes to the frequency and intensity of precipitation events, decreases in the global extent of sea ice and glaciers,

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melting of permafrost, and an acceleration in the rate of sea level rise (IPCC, 2013). Additionally, the direct effects of rising CO<sub>2</sub> levels, independent of its role as a greenhouse gas, include a stimulation of terrestrial primary productivity and increasing ocean acidification (e.g., Doney et al., 2009; Pan et al., 2014). These changes are altering the structure, functioning, and stability of Earth's ecosystems and are affecting the health, livelihoods, and well-being of people around the world (e.g., IPCC, 2014; USGCRP, 2018).

In a recent issue of this journal, Hossain (2022) presented calculations that purported to quantify decadal-scale variations in anthropogenic CO<sub>2</sub> emissions, removals of some of the emitted CO<sub>2</sub> by land and ocean processes, and the resulting accumulation of CO<sub>2</sub> in the atmosphere. These are important topics that are worthy of continued study. With the assumption that atmospheric CO<sub>2</sub> levels would increase in the future at 2.11% year<sup>-1</sup> (based on a calculation for the years 2010–2019), Hossain then projected that the CO<sub>2</sub> concentration would exceed 1200 ppm in 53 years, resulting in “severe breathing problems” and a “forthcoming deadly respiratory problem for mankind on Earth” (quoted text from p. 1 and p. 2, respectively, in Hossain, 2022). Hossain's article inaccurately describes the perturbations to the global carbon cycle and overstates the direct effects of rising atmospheric CO<sub>2</sub> levels on human health.

## 2 Criticisms of Hossain (2022)

I have four major criticisms of Hossain (2022), the last three of which are serious enough to cause me to question the value of the entire publication. Those criticisms are: (1) the data sources and methodologies were not explained with sufficient detail; (2) the reported rates of CO<sub>2</sub> emissions and removal are wildly different from other, widely-accepted values for the same carbon fluxes, and no explanation was offered for those differences; (3) the reported relative increases in atmospheric CO<sub>2</sub> are too high, resulting in a poor match to historical CO<sub>2</sub> concentrations and an overestimate of future CO<sub>2</sub> increases; and (4) the direct effects of increasing atmospheric CO<sub>2</sub> levels on human health are exaggerated; even a near-tripling of current concentrations is unlikely to cause “severe” or “deadly” respiratory effects in people. Each of these criticisms is detailed below.

### 2.1 Unclear Data Sources and Methodologies

The Abstract and only table in Hossain's article stated that the data for generating the reported carbon flux values were from “DEP, DOE, IPCC, CFC, CDIAC, IEA, UNEP, NOAA, and NASA” (Hossain, 2022). Curiously, this information was not mentioned in the Methods and Simulation section of the article, nor was any information provided about what kind(s) of data were gathered from each agency or how the data were processed. I am familiar with most, but not all, of the agency acronyms listed by Hossain. The DEP could be Department of Environmental Protection, but from which state(s) or country/countries? I cannot identify any relevant agencies with the acronym CFC, even after using the online resource acronymfinder.com (accessed 20 April 2022). The IPCC (Intergovernmental Panel on Climate Change) synthesizes published literature but does not do its own research (that is, it does not actually measure the kinds of carbon concentrations and fluxes that would be useful for generating a global carbon budget). It is difficult to formalize questions about data processing without knowing the specific kinds of data that were used, but I will give one example of basic information that was not included. It is probable that the reported growth rates of atmospheric CO<sub>2</sub> levels in Hossain (2022) were based on long-term measurements from one (or several) monitoring stations — which station(s) were used for this and were any offsets applied to account for between-station CO<sub>2</sub> concentration differences due to factors like latitude or proximity to land? No information like this was provided in Hossain's article. It is commendable that Hossain (2022) stated that the data sets are available on request. However, in my opinion, an offer to share data does not excuse the complete absence of the most basic information about the data (types, sources, and processing) that were used in Hossain's study.

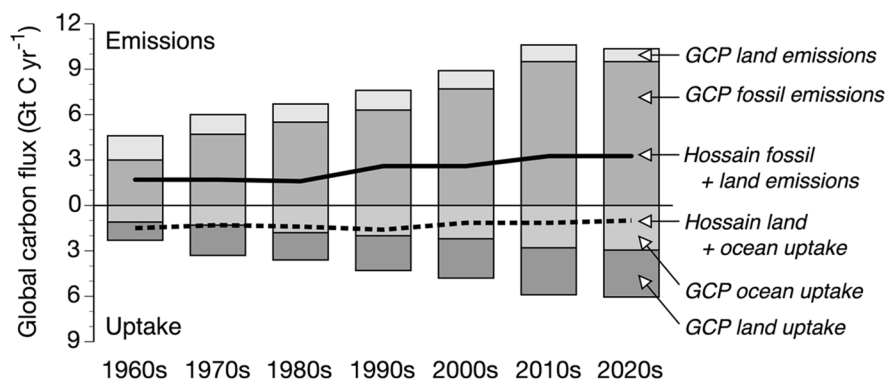
Very little information was provided about how the data from multiple agencies were used to calculate, for example, global rates of CO<sub>2</sub> emissions due to land use change or to determine oceanic uptake rates of the emitted CO<sub>2</sub>. The article states that “dynamic global environmental modelling (DGVM) simulations in MATLAB” (p. 2 in Hossain, 2022) were used to calculate CO<sub>2</sub> emissions due to land use change, but it does not indicate if the author developed his own DGVM or used one of the (at least) seventeen

different DGVMs that have been described in the literature (e.g., see summary table in Friedlingstein et al., 2022, although there the V in DGVM refers to “vegetation,” not “environmental”). Furthermore, Hossain did not provide any information about the basic structure of the DGVM, the kinds of data that went into the DGVM, or the source(s) of those datasets. The entirety of his methodology for determining CO<sub>2</sub> emissions due to land use change is, essentially, “I used an unspecified DGVM and then calculated how rates changed from year to year.” Similarly, when describing how the ocean CO<sub>2</sub> sink was calculated, Hossain cited four sources, two of which mentioned both “ocean” and “CO<sub>2</sub>” but did not specifically describe an ocean carbon sink model. The other two sources (both authored by Hossain) do not contain the word “ocean” at all, so their relevance is entirely unclear. Overall, the reader is lacking fundamental information about how Hossain generated the values in his article, an omission that is especially troubling given that the reported rates are wildly different from other widely accepted and well-documented calculations of the same carbon fluxes.

## 2.2 Inaccurate Rates of CO<sub>2</sub> Emissions and Uptake

The rates of anthropogenic CO<sub>2</sub> emissions to the atmosphere and subsequent CO<sub>2</sub> uptake by land and ocean processes reported in Hossain (2022) are different from rates that have been published elsewhere (e.g., Ciais et al., 2013; Friedlingstein et al., 2019,

2020, 2022; Le Quéré et al., 2018; Wu et al., 2013). Each year, the international Global Carbon Project updates rates of anthropogenic CO<sub>2</sub> emissions; their results are directly incorporated into IPCC synthesis reports and have become the de facto internationally accepted values of how humans have perturbed the global carbon cycle. Hossain (2022) reported that global CO<sub>2</sub> emissions from fossil fuel combustion and land use change averaged 1.7 Gt C year<sup>-1</sup> in the 1960s and increased to an average of 3.3 Gt C year<sup>-1</sup> in the 2010s. The most recent carbon budget from the Global Carbon Project also indicated that anthropogenic CO<sub>2</sub> emissions have steadily increased since the 1960s (Friedlingstein et al., 2022), but their emission rates were ~2–4 times greater than those in Hossain (2022) (Fig. 1). Similarly, there was a large discrepancy between land and ocean uptake rates of emitted CO<sub>2</sub> that were reported by Hossain (decadal averages of 1.2–1.6 Gt C year<sup>-1</sup>) versus the Global Carbon Project (decadal averages of 2.3–5.9 Gt C year<sup>-1</sup>) (Fig. 1). What is more, Hossain (2022) reported that the land/ocean sink was generally decreasing over time, a result that stands in contrast to information reported in other global carbon budgets (e.g., Friedlingstein et al., 2022) and some of the literature cited by Hossain (e.g., the title of Ballantyne et al., 2012 is “Increase in observed net carbon dioxide uptake by land and oceans during the past 50 years”). For both emissions and uptake, Hossain reported rates and average annual percent changes in those rates. However, the reported percentages do



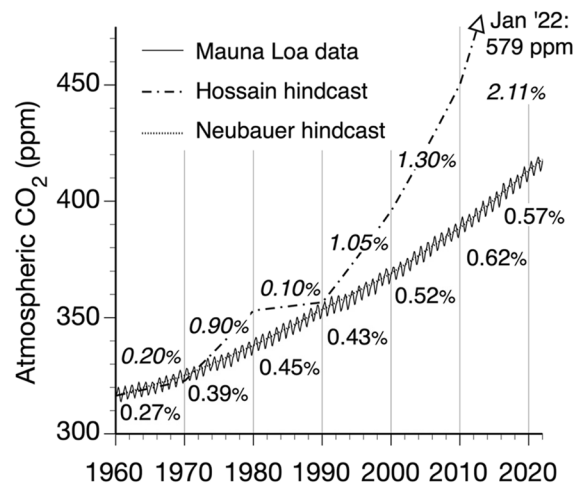
**Fig. 1** Anthropogenic CO<sub>2</sub> emissions to the atmosphere from fossil fuel combustion and land use change, plus subsequent CO<sub>2</sub> uptake by land and ocean processes. Values from Hossain (2022) are shown as lines; those compiled by the Global Carbon Project (GCP; Friedlingstein et al., 2022) are shown

as shaded bars. Total CO<sub>2</sub> emissions and uptake rates were each significantly underestimated by Hossain (2022). Decadal average rates are shown, with error bars omitted for clarity; the 2020s include only 2020 and 2021. All units are Gt C year<sup>-1</sup> = Pg C year<sup>-1</sup> = 10<sup>15</sup> g C year<sup>-1</sup>

not always make mathematical sense. As one of several examples, Hossain reported that CO<sub>2</sub> uptake by land and ocean processes decreased from 1.6 Gt C year<sup>-1</sup> in the 1990s to 1.2 Gt C year<sup>-1</sup> in the 2000s, but he also reported that the rates increased by 1.4% year<sup>-1</sup> (1990s) and 1.2% year<sup>-1</sup> (2000s). How can the decadal average rates decrease when the CO<sub>2</sub> flux increased every year (on average) by 1.2–1.4%? These discrepancies and inconsistencies raise serious questions about the validity of the data presented in Hossain's publication. I cannot exclude the possibility that Hossain's numbers actually are correct, but the burden should be on Hossain to demonstrate why his modeling/calculation approach is correct and/or to point out the errors in the approaches used by others. This was not done.

### 2.3 Overestimation of the Rise in Atmospheric CO<sub>2</sub>

Hossain (2022) reported that the annual growth of atmospheric CO<sub>2</sub> concentrations ranged from a low of 0.1% year<sup>-1</sup> during the 1980s to 2.11% year<sup>-1</sup> for the 2010s, growth rates that generally exceed the actual increase in atmospheric CO<sub>2</sub> levels. Because there are continuous, high-precision records of atmospheric CO<sub>2</sub> dating to the late 1950s (Keeling, 1960), Hossain's reported growth rates can be double-checked. In January 1960, the average monthly CO<sub>2</sub> concentration at Mauna Loa, Hawaii was 316 ppm (Fig. 2). [Note: data from different monitoring stations reveal latitudinal gradients in CO<sub>2</sub> concentrations but similar absolute rates of change (in ppm year<sup>-1</sup>; Keeling et al., 2005), so my choice of Mauna Loa over a different station does not substantially affect the following conclusions.] While Hossain's reported growth rate of 0.2% year<sup>-1</sup> during the 1960s does a decent job of reproducing the Mauna Loa CO<sub>2</sub> record during that decade, his reported growth rates from the 1970s onward lead to predicted atmospheric CO<sub>2</sub> concentrations that are substantially higher than the measured values (Fig. 2). Hossain's CO<sub>2</sub> growth rates predict an atmospheric CO<sub>2</sub> concentration of 579 ppm in January 2022, a value that is 38% greater than the measured concentration of 418 ppm. Clearly, there were mathematical errors in Hossain's calculations; instead of annual growth rates of 0.1–2.11% year<sup>-1</sup> (Hossain, 2022), I calculated that atmospheric CO<sub>2</sub> increased at roughly 0.27–0.62% year<sup>-1</sup> (decadal



**Fig. 2** Atmospheric CO<sub>2</sub> concentrations measured at Mauna Loa, Hawaii; annual CO<sub>2</sub> growth rates (in % year<sup>-1</sup>, averaged per decade) as reported in Hossain (2022) and as calculated for this communication (based on the annual change in CO<sub>2</sub> concentration from January to January); and hindcasts of CO<sub>2</sub> concentrations using those growth rates. The two hindcasts show what the CO<sub>2</sub> concentration would have been when starting from a Jan 1960 concentration of 316.43 ppm and growing at the annual growth rates reported in Hossain (2022); italicized percentages, dashed and dotted line) or calculated herein (plain text percentages, dotted line barely visible behind the raw CO<sub>2</sub> data). The seasonal cycle in the raw data was ignored for the hindcasts. For the 2020s, my calculated growth rate is the average rate for the 2020 and 2021 CO<sub>2</sub> data; Hossain (2022) used the same rate for the 2010s and 2020s. The Mauna Loa data were downloaded on 18 Apr 2022 from the Scripps CO<sub>2</sub> Program ([scrippsco2.ucsd.edu/data/atmospheric\\_co2/primary\\_mlo\\_co2\\_record.html](https://scrippsco2.ucsd.edu/data/atmospheric_co2/primary_mlo_co2_record.html))

averages; Fig. 2). The failure of Hossain's results to reproduce the history of CO<sub>2</sub> concentrations since the 1960s raises significant questions about his determination that atmospheric CO<sub>2</sub> levels will reach 1200 ppm in the next 53 years.

Combining socioeconomic scenarios with carbon cycle models provides an additional way to demonstrate that Hossain's projection of such high future atmospheric CO<sub>2</sub> concentrations is probably incorrect. The high emission scenario (SSP5-8.5) used in global modeling exercises forecasts CO<sub>2</sub> concentrations that reach 1135 ppm at the end of this century (Meinshausen et al., 2020), a concentration that is lower than what Hossain (2022) predicted for the next ~50 years. Furthermore, if CO<sub>2</sub> levels rose at the 2.11% year<sup>-1</sup> rate used in Hossain's article, they would increase from ~420 ppm today to >2000 ppm

in 2100, a near-doubling of the forecast from the high emission SSP5-8.5 scenario.

#### 2.4 Exaggeration of the Direct Health Effects of Elevated CO<sub>2</sub>

I am not aware of any evidence showing that a tripling of today's CO<sub>2</sub> concentrations to ~1200 ppm would have, to use Hossain's words, "severe" or "deadly" direct effects on human health. Furthermore, Hossain's article does not reference any literature that supports his claim. It is true that climate change, driven largely by rising concentrations of CO<sub>2</sub> and other greenhouse gases, is causing human health impacts including increased risk of heat-related morbidity and mortality, expanding transmission of vector-borne diseases, malnutrition due to reductions in crop productivity, and increased incidences of respiratory allergies and asthma (e.g., D'Amato et al., 2020; Ebi et al., 2018; Lieber et al., 2022; Limaye et al., 2018; Parham et al., 2015). However, these health effects are due to CO<sub>2</sub>-caused climate change and are not caused by direct exposure to higher CO<sub>2</sub> levels.

In the USA, current guidelines call for limiting CO<sub>2</sub> exposure over an 8–10 h period to 5000 ppm or less (OSHA, 2020). It is not until CO<sub>2</sub> concentrations reach 15,000 ppm, more than an order of magnitude above Hossain's "toxic" level of 1200 ppm, that exposure can cause "mild respiratory stimulation for some people" (USDA, 2020). None of this is to discount studies suggesting that exposure to elevated CO<sub>2</sub> concentrations can affect human health. In Hossain's list of citations, two sources reported that CO<sub>2</sub> concentrations exceeding 1000–1500 ppm could cause symptoms including headaches, fatigue, throat and nose irritation, and coughing (Cetin, 2016; Cetin & Sevik, 2016). These possible health effects are far from the "severe" and "deadly" consequences that Hossain's paper warned about. At CO<sub>2</sub> concentrations typical of poorly-ventilated indoor environments (up to several thousand ppm), there are few toxicological effects (Langford, 2005) although cognitive function may be reduced (Du et al., 2020). Jacobson et al. (2019) reported that some evidence suggests the possibility of direct health impacts at CO<sub>2</sub> concentrations as low as 1000 ppm, but also recommended additional research to determine if sustained exposure to CO<sub>2</sub> at those levels truly does affect human health. There is even some evidence from long-term (multi-week)

studies suggesting that progressive acclimation to high CO<sub>2</sub> concentrations may offset some health impacts that are seen during shorter exposure periods (USDHEW 1976 and references therein). While there may be some human health effects from direct exposure to high atmospheric CO<sub>2</sub> concentrations by the end of the century, there is no current consensus that the effects of such an exposure would be widespread, significant, toxic, or deadly. This stands in contrast with the significant and ongoing impacts to human health that are being driven by ongoing anthropogenic climate change.

### 3 Conclusions

The criticisms presented above raise the question of how Hossain (2022) should be viewed. At best, Hossain has done a poor job of describing his study and results. Perhaps his calculations of CO<sub>2</sub> emissions and uptake are regional (not global) numbers, which is why they are so much lower than the values in global carbon budgets. Also, perhaps Hossain has uncovered evidence that CO<sub>2</sub> concentrations of ~1200 ppm truly do have severe and deadly effects on human health, but he neglected to include citations to that research in his article. That is my best interpretation of his publication. However, as I have outlined in this communication, a more realistic view of Hossain (2022) is as follows: The publication does not accurately describe the historical global carbon budget (Fig. 1), it substantially overestimates likely future changes to atmospheric CO<sub>2</sub> concentrations (Fig. 2), and it reports human health impacts from CO<sub>2</sub> exposure that are not supported by evidence. Thus, each of the three major components of Hossain (2022) is seriously flawed. Readers of that article should proceed with considerable caution and severe skepticism.

**Data Availability** The information shown in Figs. 1 and 2 is taken directly from the published literature, from public data repositories, or is calculated from those literature/repository sources. No new data are presented in this submission.

#### Declarations

**Competing Interests** The author declares no competing interests.

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