Published by SET Publisher

Journal of Basic & Applied Sciences

ISSN (online): 1927-5129

Laws of Physics Define the Insignificant Warming of Earth by CO_2

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Article Info:

Keywords:
CO_2 at Mauna Loa,
per kg dry air,
psychrometric chart,
temperature,
water vapor.

Timeline:
Received: March 01, 2023
Accepted: March 26, 2023
Published: April 14, 2023

Citation: Lightfoot HD, Ratzer G. Laws of physics define the insignificant warming of earth by CO_2. J Basic Appl Sci 2023; 19: 20-28.

DOI: https://doi.org/10.29169/1927-5129.2023.19.02

Abstract:

This study provides temperature estimates about the effect of carbon dioxide (CO_2) in warming the Earth's atmosphere using readily available information. It compares the grams of water vapor per kilogram (kg) of dry air with the number of grams of CO_2 per kg of dry air. This comparison is over a year for 20 representative areas of the Earth. It shows the grams of water vapor range from 0.1 to 44.0 times that of CO_2. The increased heat content (enthalpy) of the atmosphere by CO_2 causes a maximum temperature increase of 0.006°C from the Poles to the Equator. This amount is too small to measure. These quantitative results indicate that the Tropics, representing 39.8% of the Earth's surface, contain almost three-quarters of the atmosphere's water vapor. In contrast, the Arctic and Antarctic areas at the Poles have an estimated 0.9% of the atmosphere's water vapor. Water vapor is the significant greenhouse gas that keeps the Earth from being a frozen planet.

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1. INTRODUCTION

This study is an extension of the paper "Back radiation versus CO_2 as the cause of climate change" [1] published in 2017. It uses the same calculation methods, as described below, to compare the number of water vapor molecules per molecule of CO_2. Conclusion 1 is confirmed: "Back radiation (mostly from water vapor) overrides the effect of CO_2 such that the CO_2 contribution to atmospheric temperature is so small as to be negligible."

A paper, "Earth's Temperature: The Effect of the Sun, Water Vapor, and CO_2", published in November 2022 and subsequently revised, showed that temperature warming by CO_2 is too small to measure [2].

This paper builds on both documents and uses a data set of 240 empirical values from 20 locations. These locations and the associated calculations are in the supplementary information. "Excel calculations Rev 1.xlsx" [3]. Together with the text, they provide a picture of the warming by CO_2 and the distribution of water vapor around the Earth. This paper is a good base for further investigation.

There are two bases for our work. The first is accurate measurements of CO_2 at Mauna Loa, Hawaii. From this data, we calculate the grams of carbon dioxide (CO_2) per kilogram (kg) of dry air. The second is the temperature and relative humidity obtained from AccuWeather and entered into a proven psychrometric program, Humidair, to calculate the grams of water vapor per kg of dry air. Our research in these areas is outside, in the real world—not in a laboratory.

The measurements of CO_2 at Mauna Loa began by Charles Keeling in late 1958. Originally, results came out as ppmv, parts per million by volume, but are now in the chemical term "mole fraction." We can calculate the grams of CO_2 per kilogram (kg) of dry air from the mole fraction. This value compares with the grams of water vapor per kg of dry air. The approach relies on AccuWeather [4], which only became available on smartphones in 2007, to obtain temperature and relative humidity at representative weather stations. This data is input into a psychrometric chart, a mathematical model of the Earth's atmosphere. It became available in 1904 as a chart and later as a computer program, possibly in the early 1980s. Psychrometric data is an accurate mathematical model of the Earth's atmosphere. It does not include warming by CO_2 because, as we show later, it is too small to measure.

The atmospheric researchers who developed the science behind the psychrometric chart did not find a warming effect by CO_2. Thirty-three pioneers who formed the basis for the psychrometric model are in a partial list in an article by P. Gately [5]. Some pioneers of atmospheric research are Robert Boyle, Anders Celsius, Jacques A. C. Charles, Joseph Gay-Lussac, Sir Isaac Newton, and Blaise Pascal. These pioneers were diligent, independent, and insightful, ultimately contributing to such a model. They would likely have found warming by CO_2 if it were a significant warming gas in the Earth's atmosphere.

It is essential to know that any temperature increase by CO_2 must appear in the measurements used to construct Figures **1** and **2**. The readings of temperature and relative humidity at any location measure and reflect all the heat-related physical processes, including complex ones such as the radiation and absorption of infra-red energy and any feedback effects. They also include warming by water vapor and CO_2, the local physical effects from latitude, elevation, Sun angle, Sun variability, proximity to oceans and lakes, clouds, volcanic action, and the interaction of CO_2 and water vapor with the non-GHG gases nitrogen, oxygen, and argon and any heat island effect.

We show that the amount of water vapor overwhelms the amount of CO_2 and its warming effect [6, 7]. Water vapour warms the Earth and keeps it from being a frozen planet at 33^{o}C below the current temperature level.

This study aims to quantify the warming effect of CO_2 in simple terms. We quantify our results in grams per kg of dry air rather than in Watts per square meter. It also encourages people to use a physical psychrometric chart or a computer application to check the Humidair results in Excel calculations and gain confidence. The physical psychrometric chart is at atmospheric pressure, and the temperature range is 0^{o}C to 50^{o}C [8, 9]. See the Humidair psychrometric program [10] or other computer applications [6] for different pressure and temperature ranges. For example, there is a simple description for using psychrometric data in Section 9.3 of this study [11].

2. GRAMS OF CO_2 AND GRAMS OF WATER VAPOR PER KG OF DRY AIR

In April 2021, the media reported CO_2 at Mauna Loa as 418 ppm (parts per million). The actual units are the number of CO_2 molecules per million molecules of dry

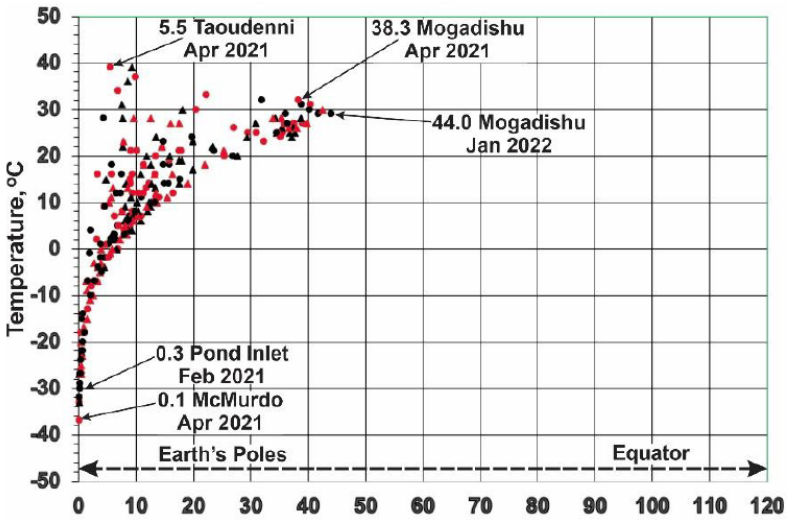


Figure 1: Grams of water vapor per gram of CO_2.

air [12], i.e., the mole fraction—418/1,000,000 = 0.000418 moles [13]. The mole fraction in dry air is essentially the same everywhere because it is not affected by water vapor or temperature dilution.

At every location on Earth, the number of molecules of CO_2 per cubic meter varies with dilution by water vapor and temperature [5]. Where water vapor and temperature are higher than at the Poles, the number of molecules of CO_2 per cubic meter is always fewer. Thus, it is necessary to calculate the grams of CO_2 at each weather station, as in column AR of the Excel calculations, to ensure accuracy.

To calculate the number of grams of CO_2 from the mole fraction, multiply it by the molecular weight, i.e., 0.000418 x 44.0059) = 0.0184 grams of CO_2 per mole of dry air. The weight of a mole of dry air is 28.9647 grams. To obtain the CO_2 as grams per kg of dry air, multiply by (1000/28.9647) = 34.54. Thus, there are 0.635 grams of CO_2 per kg of dry air. The CO_2 and water vapor units are now the same for easy comparison.

Figure **1** plots the grams of water vapor per gram of CO_2. It shows the range is from 0.1 on April 21, 2021, at McMurdo Station, in the Antarctic, to 44.0 at Mogadishu, on the Equator, on January 21, 2022.

3. MOLECULES OF WATER VAPOR VERSUS THOSE OF CO_2

The grams comparison is valid, but comparing the numbers of molecules would be more beneficial

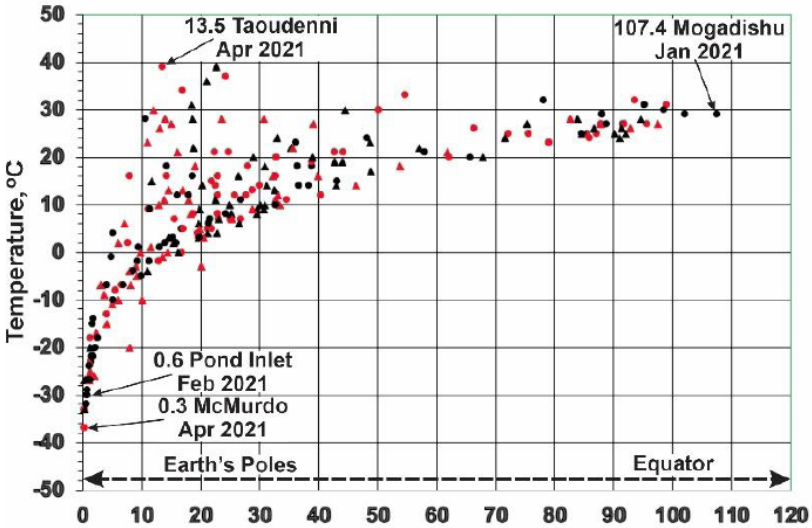


Figure 2: Molecules of water vapor per molecule of CO_2 from the Poles to the Equator. The basis is grams of CO_2 and water vapor in Figure **1** converted to molecules.

Table 1: Comparison of McMurdo and Mogadishu, Column Letters are from the Excel Calculations

C	G	H	I	R	AC	AL	BI
	April-21 2021 Montreal time	**T ˚C**	**RH, %**	**Humidity ratio grams per kg dry air**	**Enthalpy moist air, Δ from McMurdo, kJ/kg dry air**	**Specific volume cubic m/kg dry air**	**Ratio of molecules of CO_2 per cubic meter**
McMurdo	12:49	-23	71	0.070	0.0	0.669	418
Mogadishu	12:51	31	67	2.939	117.5	0.871	321
Montreal	12:40	-2	66	18.878	42.3	0.773	362
Taoudenni	12:50	39	5	2.644	83.1	0.899	311

because it is the actions of the molecules that are of interest.

The three elements involved are hydrogen, carbon, and oxygen. Their atomic weights are 1, 12, and 16, respectively. For water, H_2O, the molecular weight is: (1 + 1 + 16) = 18. The molecular weight of CO_2 is (12 + 16 + 16) = 44. Molecule for molecule, CO_2 is 44/18 = 2.44 times heavier than a molecule of water. To obtain the number of molecules, multiply the grams of water vapor per gram of CO_2 by 2.44, as in Figure **2**.

With the lowest temperature in the measurements, McMurdo Station in Antarctica has 0.3 molecules of water vapor per molecule of CO_2. As the temperature rises, water vapor warming becomes more significant than CO_2.

We assume there are 0.635 grams of CO_2 per kg of dry air. at McMurdo per kg of dry air at McMurdo (cell AR 57), which has the lowest temperature and select it as the baseline. Then, the grams of CO_2 at any of the other nineteen locations are the value at McMurdo multiplied by the inverse of the specific volumes, cubic meters per kg of dry air. For example, at Mogadishu, the CO_2 is (0.635 x (0.669/0.871)) = 0.482 grams per kg of dry air. The 0.669 and 0.871 are from column AL of Table **1**. They are cells AL57 and AL51 in the Excel calculations.

In this follow-up study, the monthly record of CO_2 from Scripps [14] allows the calculation of the grams of CO_2 per kg of dry air at each of the 20 weather stations every month.

4. HOW MANY MEASUREMENTS ARE NEEDED TO PROVIDE VALID RESULTS?

To ensure valid results, we selected 20 weather stations representative of the significant regions of the Earth, as in Table **2**. We then divided the five latitude regions into the west and east longitudes. The west longitudes are in blue for ease of identification. Table **2** shows the elevation and the pressure in Pascals converted to pressure in bar, as required by Humidair.

We recorded temperature and relative humidity for twelve months on the 21st. Figures **1** and **2** are plots of the results over one year. The calculations for this period are in Excel calculations.

5. WHERE ARE THE MOST WATER VAPOR MOLECULES?

The comparison of grams of CO_2 and water vapor is straightforward. It allows new insights into how much the number of water molecules exceeds the number of CO_2 molecules and where it occurs on Earth.

Figure **3** shows that almost three-quarters of the atmosphere's water molecules are in the Tropics, representing 39.8% of the Earth's surface. As in the Excel calculations, column AT, the number of water vapor molecules for each CO_2 molecule ranges from 83.8 to 107.4. The area between the poles and the Arctic and Antarctic Circles represents 8.4% of the Earth's surface. The range of molecules is from 0.3 to 40.4. In the remaining Earth area of 51.8%, water vapor ranges from 9.5 to 83.8 molecules per molecule of CO_2.

The median of the range of water vapor molecules in each Earth area was determined. Then this is multiplied by the percentage of the site with which it is associated. The total is 100%. The shares of each area are under the heading: "Median weighted %" in Figure **3** and facilitate comparisons.

Thus, over 91.6% of the Earth's surface, the number of water vapor molecules per molecule of CO_2 ranges from 9.5 to 107.4.

Table 2: Twenty Weather Stations Representative of the Earth's Significant Areas

					Elvation	Pressure	Bar
		Weather station	Latitude	Longitude	Meters	Pascals	
1		Pond Inlet, Canada	70˚ 42' N	77˚ 58' W	32	100941	1.009412
2	Above Article Circle	Tiksi, Russia	71˚ 38' N	128˚ 51' E	41	100833	1.008334
3		Kirkenes, Norway	69˚ 40' N	30˚ 03' E	15	101145	1.011449
4		Inuvik, Canada	68˚ 22' N	133˚ 43' W	26	101013	1.01013
5		Karamay, China	45˚ 35' N	84˚ 53' E	356	97121	0.971208
6		Portland, Oregon, USA	45˚ 31' N	122˚ 40' W	2	101301	1.01301
7	Mid-latitudes North	Milan, Italy	45˚ 28' N	9˚ 11' E	126	99820	0.998205
8		Harbin, China	45˚ 53' N	126˚ 15' E	143	99619	0.996189
9		Montreal, Canada	45˚ 30' N	73˚ 34' W	62	100582	1.005824
10		Minneapolis, USA	45˚ 59' N	93˚ 16 W	255	98299	0.982989
11		Taoudenni. Mali	22˚ 41' N	3˚ 58' W	138	99678	0.996781
12	Equator	Libreville, Gabon	0˚ 25' N	9˚ 28' E	30	100965	1.009651
13		Samarinda, Borneo	0˚ 30' S	117˚ 08' E	3	101289	1.01289
14		Mogadishu, Somalia	2˚ 03' N	45˚ 19 E	61	100594	1.005943
15		Santiago, Chile	33˚ 27' S	70˚ 40' W	533	95084	0.950837
16		Port Elizabeth, South Africa	33˚ 58' S	25˚ 36' E	61	100594	1.005943
17	Mid-latitudes South	Hobart, Australia	42˚ 53' S	147˚ 20' E	9	101217	1.012169
18		Dunedin, New Zealand	45˚ 53' S	170˚ 30' E	6	101253	1.012529
19		Rio Grande, Tierra del Fuge	53˚ 47' S	67˚ 42' W	15	101145	1.011449
20	Below Antarctic Cricle	McMurdo Station, Antarctica	77˚ 50' S	166˚ 41' E	10	101205	1.012049

6. CALCULATING THE TEMPERATURE INCREASE CAUSED BY INCREASING CO_2 IN THE ATMOSPHERE

The increase in grams of water vapor per kg of dry air increases the Earth's temperature. The rise in CO_2 also raises the temperature of the Earth's atmosphere. This increase in CO_2 increases the heat content of the air. We know the increase in the weight of CO_2 between McMurdo and the other 239 weather readings, the difference in temperature, and the specific heat. Thus, we can calculate the increase in heat content (enthalpy) at each weather station. We know the difference in temperature from McMurdo to Mogadishu is 69^{o}C; the heat content difference is 117.5 kilojoules (kJ) per kg of dry air or 1.703 kJ per degree C.

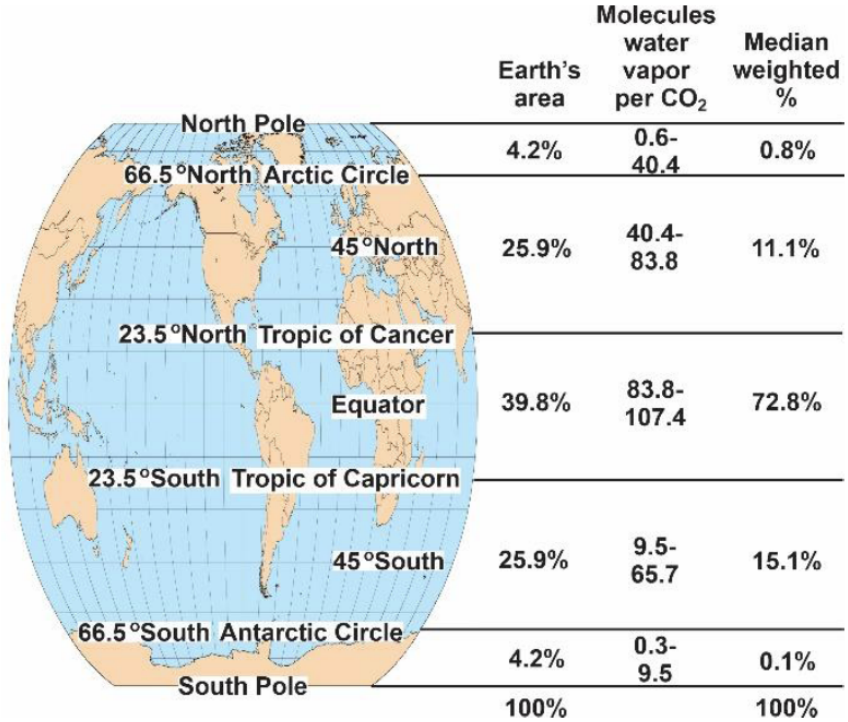
We know the grams of CO_2 are lower everywhere where the temperature is higher than at McMurdo (column BB). For example, the CO_2 at Taoudenni, Mali, in the Sahara Desert, is 0.162 lower than at McMurdo. These values are on the left axis of Figure **4**, and the increase in temperature is along the horizontal axis.

The black triangles are values in the Arctic, and the red triangles are in the Antarctic. The black circles are the remaining values on 91.6% of the Earth's surface. The maximum temperature increase by CO_2 coincides with the maximum number of water vapor molecules. The reason for this can be the subject of future work.

The maximum temperature increase by CO_2 is 0.0060^{o}C at Taoudenni. This increase is over a range of CO_2 of 311 molecules per kg of dry air (cell BH267) to 418 (cell BI57). In Figure **4**, "ppm"="molecules per million molecules of dry air". The maximum increase in the CO_2 content of the atmosphere over the range of 311 to 418 is 0.166 grams per kg of dry air (cell AV267).

7. COMPARING WARMING BY CO_2 AND BY WATER VAPOR

The most increase in heat content by CO_2 occurred at Mogadishu. It was 0.000845 kJ/kg dry air on April 21, 2021 (cell BE51) and February 21, 2022 (cell AY320). The heat content on April 21, 2021, was 69.4 kJ per kg



	Earth's area	Molecules water vapor per CO_2	Median weighted %
North Pole to 66.5°North Arctic Circle	4.2%	0.6-40.4	0.8%
66.5°North Arctic Circle to 45°North	25.9%	40.4-83.8	11.1%
45°North to 23.5°North Tropic of Cancer to Equator	39.8%	83.8-107.4	72.8%
Equator to 23.5°South Tropic of Capricorn to 45°South	25.9%	9.5-65.7	15.1%
45°South to 66.5°South Antarctic Circle to South Pole	4.2%	0.3-9.5	0.1%
	100%		100%

Figure 3: The number of molecules of water vapor per molecule of CO_2 over areas of the Earth.

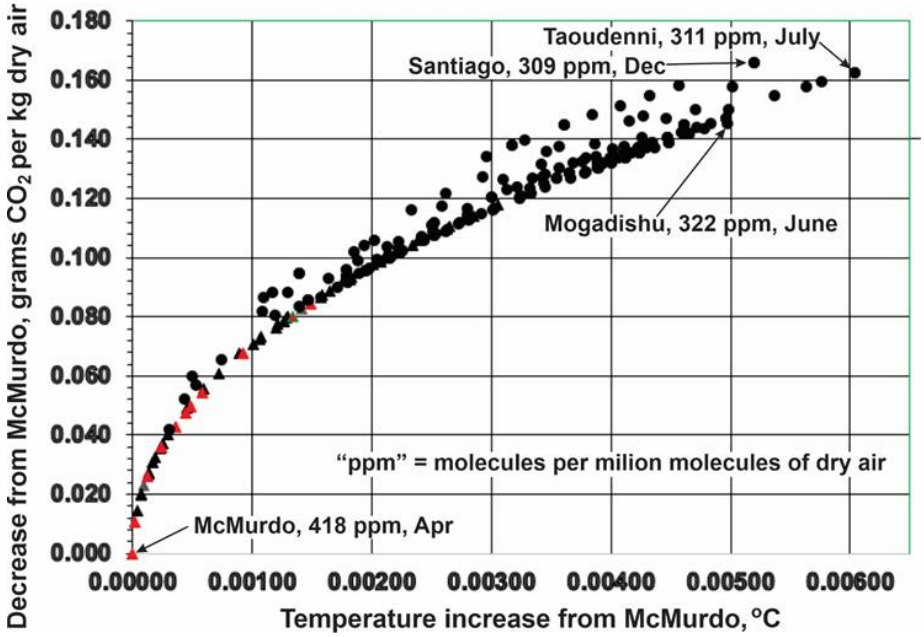


Figure 4: Increase in temperature from McMurdo versus grams of CO_2.

of dry air (cell AH51) and 117.5 kJ per kg of dry air for moist air (cell AC51).

The heat content by CO_2 was a tiny part of the heat content by dry air and moist air, i.e., (0.000845/69.4) = 0.00122% of dry air and (0.000845/117.5) = 0.000719%. of moist air.

This calculation method shows warming by CO_2 is much smaller than warming by water vapor and is too small to measure.

8. SUMMARY AND CONCLUSIONS

In this follow-up study, a straightforward approach calculates the grams of CO_2 per kg of dry air at each of

the 20 weather stations for the twelve months of measurements. Comparing these results with the computed grams of water vapor per kg of dry air by psychrometric data in the Excel calculations provides valuable insights.

Calculating the increase in the heat content of the atmosphere caused by increased CO_2 is the method for determining the rise in Earth's temperature. An increase from 311 ppm to 418 ppm causes a maximum rise of 0.006°C from McMurdo to Taoudenni, Mali, in the Sahara Desert. This value indicates the temperature increase is too small to measure, i.e., negligible [15].

The current climate models in IPCC reports rely on a significant increase in warming by CO_2. Because CO_2 cannot cause measurable warming of the atmosphere, these models give erroneous results [16] [17].

Additional Conclusions

8.1. For 39.8% of the Earth's surface, the number of water vapor molecules per molecule of CO_2 ranges from 83.8 to 107.4, accounting for approximately three-quarters of the atmosphere's water vapor.

8.2. For the 8.4% of the Earth's surface represented by the Arctic and Antarctic Circles, water molecules range from 0.3 to 40.4 per molecule of CO_2, accounting for less than 1% of the atmosphere's water vapor.

8.3. For the remaining 51.8% of the Earth's surface water vapor, molecules per CO_2 molecule range from 9.5 to 83.8 and account for an estimated one-quarter of the atmosphere's water vapor.

8.4. The number of CO_2 molecules over the Earth ranges from (1/0.3) = 333% to (1/107.4) = 0.93% of the molecules of water vapor.

8.5. The number of water molecules overwhelms the number of CO_2 molecules everywhere on Earth except sometimes at the Poles in wintertime.

8.6. There are so few molecules of CO_2 compared to water vapor, ranging from 1/0.3 to 1/107.4, that the warming effect of CO_2 is negligible.

8.7. The maximum increase in temperature by CO_2 from McMurdo to Taoudenni is 0.006°C. Even if CO_2 rose to 800 molecules of CO_2 per million molecules of dry air, the temperature rise would still be too small to measure.

This study is a significant step forward in the science of the Earth's atmosphere. It provides robust quantitative evidence that the overall warming by CO_2 is insignificant, and water vapor is the most significant greenhouse gas.

A significant conclusion is that non-climate scientists using the methods of this study can move climate science forward using available and reliable information.

ACKNOWLEDGEMENTS

The former co-author of H. D. Lightfoot, Orval Mamer, now deceased, taught much about writing up studies for publication. Orval had an excellent knowledge of chemistry and could apply it skillfully. Paul Samborsky has broad general knowledge and is always keen to review and improve my work. Gerald Ratzer, my current co-author, is continually questioning to improve the paper. He is very good at digging out new and relevant information.

9. APPENDIX: DETAILED CALCULATIONS

The cell numbers below are in the supplementary information of Excel calculations. The Excel calculations rely on the Humidair psychrometric program running in the background. Bringing in the Excel spreadsheets will reveal that some of the calculation cells in black have spurious data. To the right of them will be the correct numbers in blue. All cells of calculation numbers in this text refer to the numbers in blue.

9.1. McMurdo, April 21, 2021

1. Temperature and relative humidity are in cells H57 and I57. Humidair gives 0.070 grams of water per kg of dry air, cell R57.

2. CO_2 is 418 molecules of CO_2 per million molecules of dry air. This value converts to 0.000418 moles per mole of dry air. This value converts to 0.635 grams of CO_2 per kg of dry air, cell AR 57.

3. The ratio of water to CO_2 is (0.070/0.635) = 0.11 grams of water per gram of CO_2, cell AS57.

4. Applying molecular weights gives (0.11 x (44/18)) = 0.3 molecules of water per molecule of CO_2, cell AT57.

9.2. Mogadishu, April 21, 2021

1. Temperature and relative humidity are in cells H51 and I51. Humidair gives 18.878 grams of water per kg of dry air, cell R51.

2. The specific volume at McMurdo is 0.669 cubic meters per kg of dry air, cell AL57.

3. The specific volume at Mogadishu is 0.871 cubic meters per kg of dry air, cell AL51.

4. The grams of CO_2 at Mogadishu = (0.0184 x (0.669/0.871)) = 0.0141 grams of CO_2, cell AR51.

5. The grams of CO_2 per kg of dry air = 0.0141 x 34.5396 = 0.488, AR51

6. The ratio of water vapor to CO_2 is: (18.878/0.488) = 38.7 grams of water per gram of CO_2, cell AS51.

7. Applying molecular weights gives (38.7 x (44/18)) = 94.5 molecules of water per molecule of CO_2, cell AT51.

The numbers in these calculations appear in Figures **1** and **2**. The monthly average mole fraction of CO_2 reported from March 2021 to February 2022 is from the Scripps data [10]. Then, calculate the grams of CO_2 per kg of dry air as in column AR. The specific volume is the basis for calculating the grams of CO_2 for each of the 20 locations. The base reference for all sites is McMurdo, April 2021, Row 57, in the Excel calculations, where the temperature is the lowest in the set at -37°C in April 2021.

Plots of the data are in the list at the bottom of the window with the Excel calculations.

9.3. How to Check the Calculations by Humidair in the Excel Calculations

The easiest way to check the calculations by Humidair is to use a psychrometric chart or computer application. For example, use an online interactive psychrometric chart [5] at: https://www.flycarpet.net/en/psyonline. Go to the Excel calculations and Montreal in cell H20 and collect a temperature of -2°C and relative humidity of 66%. Put these numbers opposite “T dry” and “Rel Humid”, respectively. Then click on the box: “Or input data for air properties” to insert a blue checkmark. Then, scroll down to “Submit” and click on it. The chart to the right will show a green marker for the input values. The humidity ratio on the right vertical axis is just over 2. The humidity ratio in the list to the left is 2.113 grams of water per kg of dry air. Cell R20 of the Excel calculations shows 2.129 grams of water per kg of dry air. The pressure difference caused by elevation, i.e., 101,325 Pa versus 100,582 Pa, creates a slight difference in these values.

SUPPLEMENTAL MATERIALS

The supplemental materials can be downloaded from the journal website along with the article.

REFERENCES

[1] Lightfoot HD, Mamer OA. Back radiation versus CO_2 as the cause of climate change, Energy and Environment, Sage Publishing 2017. https://doi.org/10.1177/0958305X17722790

[2] Lightfoot HD, Ratzer G. Earth’s Temperature: The Effect of the Sun, Water Vapor, and CO_2. Journal of Basic & Applied Sciences 2022; 18: 87-97. https://doi.org/10.29169/1927-5129.2022.18.10

[3] Excel Tutorial for beginners, Excel made easy. Available at: https://www.youtube.com/watch?v=0tdlR1rBwkM

[4] AccuWeather, About us. Available from: https://corporate.accuweather.com/company/about-us/

[5] Gately P. Psychrometric chart celebrates 100th Anniversary: by P. Gatley, P.E., Fellow/Life Member ASHRAE, Table 2. Available at: http://www.handsdownsoftware.com/Psychrometrics-100th-Bday.pdf

[6] van Wijngaarden WA, Happer W. Dependence of Earth’s Thermal Radiation on Five Most Abundant Greenhouse Gases, arXiv:2006.03098v1 [physics.ao-ph] 4 Jun 2020.

[7] Kiehl JT, Trenberth KE. Earth’s Annual Global Mean Energy Budget, Bulletin of the American Meteorological Society 1997. https://doi.org/10.1175/1520-0477(1997)078<0197:EAGMEB>2.0.CO;2

[8] Online Interactive Psychrometric Chart. Available at: https://www.flycarpet.net/en/psyonline

[9] American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Technical Resources, Psychrometrics, ASHRAE Psychrometric Chart App. Available at: https://www.ashrae.org/technicalresources/bookstore/psychrometrics

[10] MegaWatSoft Psychrometric Calculator, HumidAir Excel Add-In v3.1. This program is available for purchase or rental www.megawatsoft.com

[11] Practical HVAC, Psychrometry - properties of air. Available at: https://www.practicalhvac.com/uncategorized/properties-of-air-psychrometry/

[12] Tans P, Thoning K. How we measure background CO_2 levels on Mauna Loa, NOAA Global Monitoring Laboratory, Boulder, Colorado, September 2020. Available at: https://gml.noaa.gov/ccgg/about/co2_measurements.html

[13] Global Monitoring Laboratory, Earth System Research Laboratories, Trends in Atmospheric Carbon Dioxide. Available at: https://gml.noaa.gov/ccgg/trends/

[14] Scripps CO_2 program, Mauna Loa Observatory, Hawaii, “monthly_in_situ_co2_mlo.csv”. Available at: https://scrippsco2.ucsd.edu/data/atmospheric_co2/mlo.html [

[15] Clark R. Reject AR6, Ventura Photonics Climate Post 6, VPCP 006.1a. Available at: https://venturaphotonics.com/files/VPCP_006.1_RejectAR6.pdf

[16] Scafetta N. MIP6 GCM Validation Based on ECS and TCR Ranking for 21st Century Temperature Projections and Risk Assessment. Atmosphere 2023; 14(2): 345. https://doi.org/10.3390/atmos14020345