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Earth's Temperature: The Effect of the Sun, Water Vapor, and CO₂

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Abstract:

The purpose of this study is to show the Sun controls the Earth's temperature daily and over decades and millennia. A secondary objective is to show CO₂ contributes to the warming of the Earth through increased enthalpy (heat content). The methodology is to record temperature and relative humidity at many weather stations around the globe to provide a picture of the constantly changing atmosphere over twelve months. Daily measurements of the molecular fraction of CO₂ are converted to weight to calculate the increasing enthalpy of the atmosphere. The Sun controls Earth's temperature through water vapor up to the dewpoint temperature line and by direct heat radiation from the Sun above it. The enthalpy contribution by CO₂ from 1750 to 2022 was up to 0.0000049 kJ/kg of dry air, equivalent to a temperature increase of 0.000181°C over 272 years. The effect of CO₂ on warming the Earth has a negligible increase in Earth's temperature.

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1. INTRODUCTION

This study aims to determine the role of the Sun and CO₂. Currently, there are two choices of approach to the problem. One is the theory promoted by the Intergovernmental Panel on Climate Change (IPCC). It claims the absorption of infrared radiation by greenhouse gases heats the air. For example, it claims to increase CO₂ in the atmosphere can raise the Earth's temperature to dangerous levels, such as 1.5°C above the temperature in preindustrial days [1].

The second theory promoted by Syukuro Manabe and others says: "the Earth operates essentially as a thermodynamic machine, utilizing evaporation, condensation, and precipitation (Latent Heat), and convection and advection (Sensible Heat, SH) [2]. This study relies on the thermodynamic approach because the Earth's temperature depends on energy from the Sun. The Milankovitch Cycles [3] demonstrate this in the IPCC Fourth Assessment Report (AR4). The solar maxima and minima also show the effect [4].

All of the factors noted by Manabe [5, 6], plus the infrared radiation promoted by the IPCC, are included in the hourly measured temperature readings at weather stations around the Earth. The readings also include relative humidity (RH). Temperature and RH provide access to psychrometric data—the thermodynamic properties of humid air—the atmosphere. Psychrometric data describes the physical thermodynamic properties of the Earth's atmosphere [7].

Research about the Sun over the past three decades indicates it goes through cycles when its energy input to the Earth increases and decreases, i.e., the solar maxima and minima. A grand solar minimum occurred as the Maunder Minimum around 350 to 400 years ago. The temperature of the Earth fell enough that the Thames River in England froze over for several consecutive years. This event was thermodynamic. An improved understanding of the internal workings of the Sun indicates the Sun entered a solar minimum in mid-2020, another thermodynamic event. The Earth's temperature is estimated to fall by approximately 1°C by 2030. This event contrasts with the IPCC estimate that Earth's temperature will increase over the same period.

Thermodynamic properties of humid air support the second theory. All the Earth's atmosphere contains water vapor: "humid air." Psychrometric data

documents the thermodynamic properties of humid or moist air [8]. This data was developed around 1900 [9, 10]. W. H. Carrier constructed it as a convenient graph in 1904 for designing Heating, Ventilating, and Air Conditioning (HVAC) systems for buildings. He needed a convenient method for determining how much water or heat to add or to remove. HVAC engineers use psychrometric data daily to design buildings of all kinds. Moisture problems are solved using psychrometric data.

Psychrometric data is a sound and proven science. It is available as a chart, computer program, or cellphone app. See Appendix A. For example, "The HumidAir Excel Add-In library calculates 35 thermodynamic properties of humid (moist) air. It allows 21 different combinations as input variables for calculations. Input variables are pressure, dry bulb temperature, wet bulb temperature, dew point temperature, relative humidity, humidity ratio, enthalpy, entropy, and volume. It is fully integrated with Excel and works in the same way as any other Excel function" [11].

Today, there is a similar program for smartphones by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) [12]. These computer programs can provide more data in a more convenient format than reading charts and noting the results on paper. The programs also have access to more extensive air and water vapor properties.

This study uses the thermodynamic properties of the Earth's atmosphere to show the Sun controls Earth's temperature daily and how it does so. This study closes the loop of thermodynamics and control of Earth's temperature by the Sun over millennia, centuries, decades, and now daily.

This study shows the Sun controls the Earth's temperature daily through water vapor and direct heat radiation. It also shows how the thermodynamic properties of CO₂ fit into the scenario.

2. INTRODUCTION TO THE METHODOLOGY

The thermodynamic properties of the Earth's atmosphere are constantly changing. Daily the Sun rises and sets, exposing each area of the planet to active warming, and the length of the day changes through the seasons. Various amounts of water transform into water vapor and, in the process, absorb enormous amounts of heat that are later released as the water vapor condenses. This process can become

violent as warm, moist air rises, and the sudden heat release can cause thunderstorms [13].

This study uses a new method for creating a picture of the Earth's dynamic atmosphere using thermodynamics. The technique uses current technology [14] and psychrometric data to show the Sun controls the Earth's temperature daily. Figure 1 is a diagram of the average global energy balance and represents the best estimates of averages at the beginning of the 21st century, as adapted from Wild *et al.* (2015 and 2019) [15]. Figure 1 shows the distribution of the Sun's energy. From Figure 1, global warming is $(398 - 239) = 159 \text{ W m}^{-2}$.

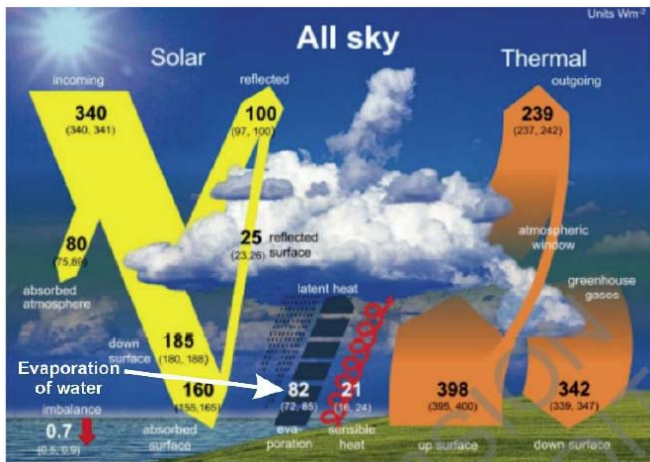


Figure 1: Adapted from a schematic representation of the global mean energy budget of the Earth. This figure is the upper part of Figure 7.2 of AR6 [16].

The numbers are Watts per square meter (W m^{-2}). The evaporation of water by the Sun is large enough that it is identified separately as 82 W m^{-2} . It is $(82/(160 + 342)) = 16.3\%$ or one-sixth of the energy input to the Earth [17]. A percentage of 16.3% is an enormous amount of water evaporated. As the energy radiation to the Earth originates from the Sun, the Sun determines the atmosphere's water content or humidity ratio. The energy in the phase changes of water is essential in transferring heat from locations with more to those with less [18]. This heat transfer keeps the Earth within a temperature range where many forms of life flourish [19].

Water vapor is an integral and vital part of the atmosphere. These properties are essential to understanding the Earth's atmosphere. Curiously, there is no mention of psychrometric data in the Intergovernmental Panel on Climate Change (IPCC) Fifth or Sixth Assessment reports, AR5 and AR6.

In this study, the Humidair program ascertains the humidity ratio (water content), dew point temperature, the enthalpy of both the dry and moist air, and the specific volume. All this from entering the pressure, temperature, and RH.

3. METHODOLOGY FOR CREATING A PICTURE OF THE CONSTANTLY CHANGING WATER VAPOR CONTENT OVER TIME

The methodology simultaneously gathers the temperature and relative humidity (RH) at 20 weather stations worldwide for all seasons. Figure 2 shows the sites representing locations from the Poles to the Equator. The temperature and RH are input to a psychrometric program that calculates the humidity ratio (water content) and dew point. Each set of readings provides a picture of temperature, RH, water vapor, and dew point at each location from the Poles to the Equator.

Plotting the results over the four seasons shows what happens in the dynamic and constantly changing atmosphere. For this study, measurements were recorded simultaneously on the 21st of the month at random Montreal times over one year, which includes two equinoxes, two solstices, and the time between them. The result is 240 points for plotting to give the picture over one year, as in Figure 2. Recording more frequently over shorter periods obtains similar results. See Appendix B.

Each temperature measurement results from all the factors that affect the Earth's temperature. Some of these factors are volcanoes, ocean currents, cosmic rays, and radiation absorbed by greenhouse gases. Some weather stations are in the Arctic and Antarctic, the Equator, and the Sahara Desert to show temperature extremes.

AccuWeather [14] on a smartphone is a convenient method of obtaining real-time values of temperature and RH at each weather station. The AccuWeather measurements are updated every hour. Because it is possible to run through the list in twenty minutes, an immediate check can ensure they are within the same hour, which is essentially simultaneously. The measurements are the input data for the Excel spreadsheets in Supplementary Information. With Humidair in the background, Excel calculates the humidity ratio, the dew point, and other properties in the Supplementary Information.

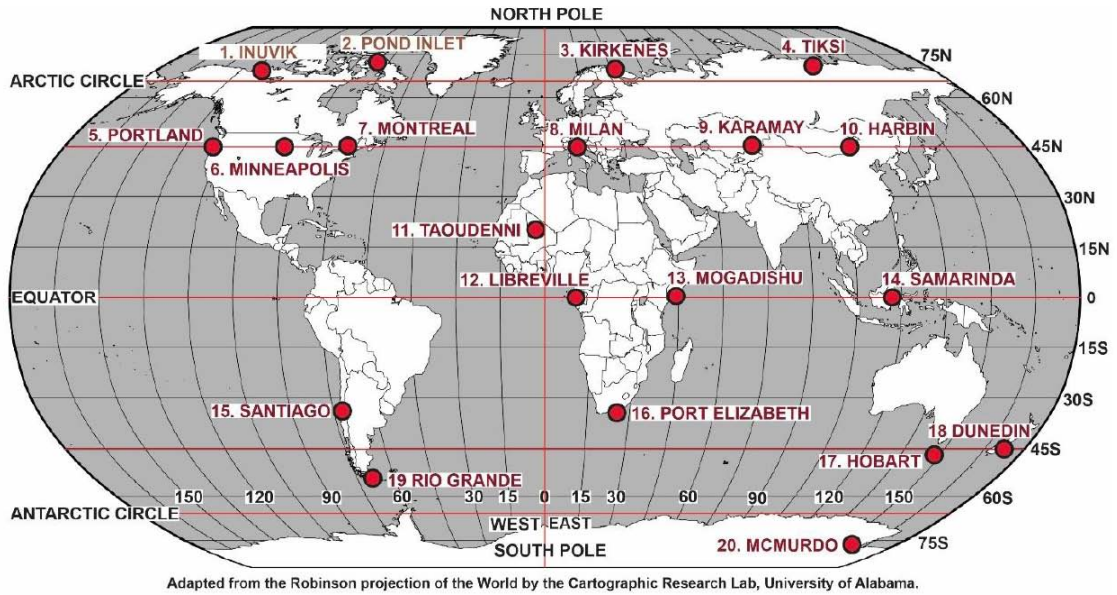


Figure 2: The locations of twenty weather stations that represent a significant area of the Earth.

Figure 2 shows the weather station locations, and Table 1 describes the location by latitude, longitude, elevation, and pressure [20].

4. PLOTTING THE RESULTS

Figure 3 plots the air temperature versus water vapor content for the 20 weather stations for twelve months

from March 21, 2021, to February 21, 2022, for a total of 240 points. The plot shows the extreme temperature and water vapor variability between 20 locations on Earth over a year. For example, the temperature difference between the Poles and the Equator on any day can be between 45°C to 70°C. The difference in water vapor can be up to 20.8 grams of water per kg of dry air. These are huge differences and measure the

Table 1: Number, Name, Location, Elevation, and Air Pressure of each Weather Station

	Weather station	Latitude	Longitude	Elevation, m	Pressure, bar
1	Inuvik, Canada	68° 22' N	133° 43' W	26	1.01013
2	Pond Inlet, Canada	72° 42' N	77° 58' W	32	1.00941
3	Kirkenes, Norway	69° 40' N	30° 03' E	15	1.01145
4	Tiksi, Russia	71° 38' N	128° 51' E	41	1.00833
5	Portland, Oregon, USA	45° 31' N	122° 40' W	2	1.01301
6	Minneapolis, USA	45° 59' N	93° 16' W	255	0.98299
7	Montreal, Canada	45° 30' N	73° 34' W	62	1.00582
8	Milan, Italy	45° 28' N	9° 11' E	126	0.99820
9	Karamay, China	45° 35' N	84° 53' E	356	0.97121
10	Harbin, China	45° 53' N	126° 15' E	143	0.99619
11	Taoudenni, Mali	22° 41' N	3° 58' W	138	0.99678
12	Libreville, Gabon	0° 25' N	9° 28' E	30	1.00965
13	Mogadishu, Somalia	2° 03' N	45° 19' E	61	1.00594
14	Samarinda, Borneo	0° 30' S	117° 08' E	3	1.01289
15	Santiago, Chile	33° 27' S	70° 40' W	533	0.95084
16	Port Elizabeth, South Africa	33° 58' S	25° 36' E	61	1.00594
17	Hobart, Australia	42° 53' S	147° 20' E	9	1.01217
18	Dunedin, New Zealand	45° 53' S	170° 30' E	6	1.01253
19	Rio Grande, Tierra del Fuego	53° 47' S	67° 42' W	15	1.01145
20	McMurdo Station, Antarctica	77° 50' S	166° 41' E	10	1.01205

dynamic nature of the Earth's atmosphere. From Figure 3 and the Supplementary Information, the level of water vapor varies from 0.07 grams of water per kg of dry air in McMurdo Station in Antarctica to 18.878 in Mogadishu, close to the Equator on the east coast of Africa. There is 270 times more water in the air in Mogadishu than in McMurdo.

In Figure 3, the psychrometric program calculates the dew point temperature that plots a blue line. The area under the blue dew point temperature line is where water vapor condenses to water.

As an example of the temperature split, on the right side of Figure 3, the temperature measured at Mogadishu on the Equator is 32°C, and RH was 62% from the Supplementary Information. Water vapor causes the dew point temperature of 23.8°C. Exposure to direct Sun heat radiation increases the temperature to 32°C, 8.2°C above the dew point line.

5. WHAT CAUSES THE TEMPERATURE ABOVE AND BELOW THE DEW POINT TEMPERATURE CURVE?

The split occurs regardless of how much Sun energy reaches Earth. For example, the separation occurs when volcanoes emit ash into the atmosphere, reducing the Sun's rays and cooling the Earth. Or when cosmic rays cause clouds.

In Figure 3, where there is little water vapor, such as at Taoudenni in the Sahara Desert on the left side of the figure, the Sun's direct influence on the temperature is

most significant. It has much less impact with more water vapor on the right side of Figure 3.

The evidence presented in this study shows that the Sun and water vapor determine the temperature at all locations around the Earth daily.

6. HOW DOES CO₂ FIT INTO THE PICTURE?

The essential item is the number of molecules of CO₂ per cubic meter diminishes from the Poles to the Tropics, as in Table 2.

Increasing CO₂ increases the mass of the atmosphere. From 1750 to 2022, the number of molecules of CO₂ increased from 270 to 418 ppm. Table 3, adapted from Tans and Thoning, shows the number of molecules of CO₂ per million molecules of dry air. For CO₂ on Feb 1, 2022, the mole fraction is 0.000418. Converted to weight, it is 0.0184 grams [21] per kg of dry air which is 0.0000184 kilograms.

From 1750, when CO₂ was 270 ppm, the Earth's temperature range from the Poles to the Equator was approximately the same as today. Thus, the Supplementary Information records are sufficiently valid to provide good results when applying current data to the range from 1750 to 2022.

The psychrometric data includes moist and dry air enthalpy for each of the 240 weather station measurements of temperature and RH. See the Supplementary Information columns Z to AJ.

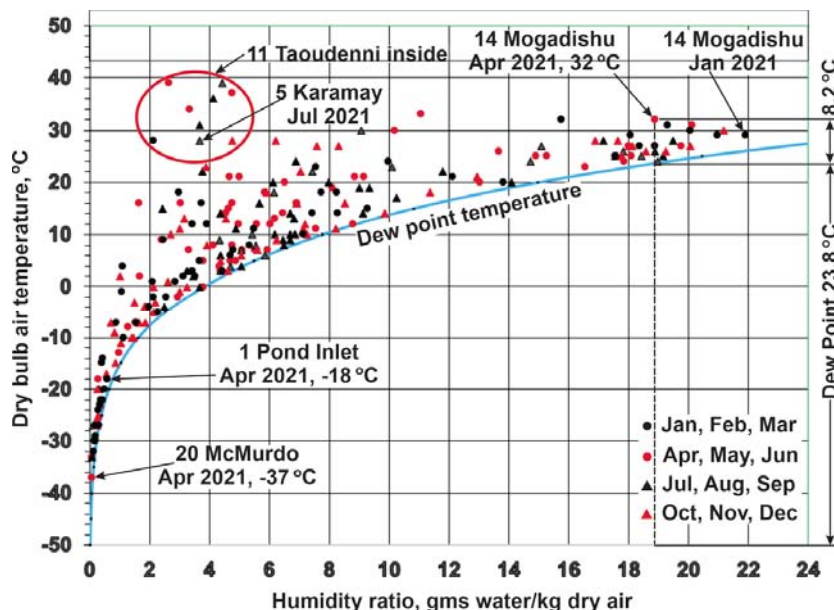


Figure 3: A plot of 240 points from Mar 21, 2021, to Feb 21, 2022.

Table 2: Comparison of Conditions at Four Weather Stations

A	B	C	D	E	F	G	H	I	J
April 21, 2021 Montreal time	T °C	RH %	Dew Point °C	Sun, max angle above horizon degrees	Humidity ratio, grams water/kg dry air	Enthalpy dry air, kJ/kg dry air	Enthalpy moist air, kJ/kg dry air	Specific volume, cubic m/kg dry air	Molecules of CO ₂ per cubic meter
McMurdo 12:49	-37	63	-41.1	0.61	0.070	0.0	0.0	0.669	418
Montreal 12:40	-2	91	-3.1	56.33	2.939	35.2	42.3	0.779	363
Mogadishu 12:51	32	62	23.2	79.27	18.878	69.4	117.5	0.871	323
Taoudenni 12:50	39	6	-4.5	78.63	2.644	76.4	83.1	0.899	311

Table 3: Molecules of CO₂ Per Million Molecules of Dry Air. Adapted from Tans and Thoning, Version Updated September 2020 [22]

	Dry air	Dry air	1.808% wet air
	Sep 20, 2020	Feb 1, 2022	Apr 21, 2021
Nitrogen	780,900	780,897	766,210
Oxygen	209,360	209,359	205,421
Water vapor	0	0	18,808
Argon	9,300	9,300	9,125
Carbon dioxide (CO ₂)	413	418	410
Neon	18	18	18
Helium	5	5	5
Methane (CH ₄)	2	2	2
Krypton	1	1	1
Trace species (each less than 1)	1	1	1
Totals	1,000,000	1,000,002	1,000,001

In Table 2, the enthalpy of McMurdo adjusted to zero serves as a baseline. The enthalpies of the other locations are adapted to suit. Table 2 includes the Sun angle because the air's enthalpy, or heat content, comes from the Sun and is related to the Sun angle—a higher Sun angle means higher enthalpy. Measurement of enthalpy is in heat units, i.e., kilojoules per kg of dry air.

What is the warming effect of CO₂ on the air by enthalpy? Table 2 shows that Mogadishu's enthalpy is 117.5 kJ/kg air. The temperature difference from McMurdo is 69°C. Thus, there is 1.703 kJ per degree Celsius. Table 4 shows kilograms (kg) of CO₂ at each location, the enthalpy change between McMurdo and each site, and the equivalent temperature increase

when CO₂ is 418 ppm at McMurdo. For this study, the specific heat of CO₂ is 0.833 kJ/kg K [23], which is the value for Earth's average temperature of 15°C.

The upper part of Table 4 shows the conditions at 418 ppm of CO₂. The middle part shows the conditions at 270 ppm, the level in preindustrial days. The lower part shows the conditions if CO₂ rose to 800 ppm. The effect of using thermodynamics on the contribution of CO₂ shows a maximum increase in the Earth's temperature by CO₂ since 1750 is (0.000509 – 0.000329) = 0.000181°C. This temperature is negligible when compared to the estimated increase of 0.8°C to 1.3°C from 1850 to 2019 in AR6 [24]. The indication is that warming by CO₂ has been an infinitesimal part of the warming of the Earth's atmosphere since 1750.

Table 4: Comparison of Enthalpy

A	B	C	D	E	F
McMurdo to higher temperature locations	Kilograms CO ₂ per kg dry air	ΔT °C	Specific heat of CO ₂ , kJ/kg K	Maximum CO ₂ enthalpy change, kJ/kg dry air	Equivalent Temperature Increase, °C
Conditions at 418 ppm					
McMurdo	0.0000184	0	0.833	0	0
McMurdo to Montreal	0.0000160	35	0.833	0.000466	0.000274
McMurdo to Mogadishu	0.0000142	69	0.833	0.000816	0.000479
McMurdo to Taoudenni	0.0000137	76	0.833	0.000867	0.000509
Conditions at 270 ppm					
McMurdo	0.000019	0	0.833	0	0
McMurdo to Montreal	0.0000103	35	0.833	0.000301	0.000177
McMurdo to Mogadishu	0.0000092	69	0.833	0.000529	0.000310
McMurdo to Taoudenni	0.0000089	76	0.833	0.000561	0.000329
Conditions at 800 ppm					
McMurdo	0.0000352	0	0.833	0	0
McMurdo to Montreal	0.0000306	35	0.833	0.000892	0.000524
McMurdo to Mogadishu	0.0000272	69	0.833	0.001561	0.000917
McMurdo to Taoudenni	0.0000262	76	0.833	0.001659	0.000974

Calculating the enthalpy of all greenhouse gases identified by the IPCC with Global Warming Potentials is similar to that of CO₂. Still, it is much less because there are fewer molecules per million molecules of dry air. For example, there are only two methane molecules per million molecules of dry air. The mole fraction is 0.000002, which converts to 0.000000088 kg or 5% of that of CO₂.

As in Table 4, if the CO₂ were to increase to 800 ppm, 0.0000352 grams per kg of dry air at McMurdo, the enthalpy increase to Taoudenni would be (0.0000262 x 0.833 x 76) = 0.001659 kJ/kg. The equivalent temperature increase is (0.001659/1.703) = 0.000974°C.

Other combinations of locations in the Supplementary Information can give similar results. A new set of temperature and RH measurements would also give similar results. See Appendix B.

7. SUMMARY OF THE RESULTS

1. Through thermodynamics, the Sun controls the Earth's air temperature over millennia, centuries, decades, and daily. The control by the Sun is slightly modified from time to time by cosmic rays, volcanoes, and ocean currents.

2. The Sun controls Earth's temperature daily, indirectly by water vapor and directly by radiating heat energy. The dew point temperature determines the split between the two.
3. Carbon dioxide increases the mass content of the atmosphere and, therefore, its enthalpy. It increased by 0.0000049 kg per kg of dry air at Taoudenni from 1750 to 2022, equivalent to a temperature increase of 0.000181°C. The latter appears to be the most accurate current estimate of the rise in the Earth's temperature by CO₂ from preindustrial days to today.
4. The Sun controls the effect of enthalpy by CO₂, which varies according to its location on Earth.
5. The current enthalpy contribution of CO₂ at 418 ppm from McMurdo to Taoudenni increases by 0.000867 kJ/kg dry air. The equivalent temperature increase is 0.000509°C.
6. If the number of molecules of CO₂ per million molecules of dry air increased to 800 ppm at McMurdo, the contribution of enthalpy by CO₂ would increase the enthalpy at Taoudenni by 0.001659 kJ/kg dry air, equivalent to a temperature increase of 0.000974°C.

- Calculating the enthalpy of all greenhouse gases identified by the IPCC with Global Warming Potentials is like that of CO₂. Still, the effect is much less because of fewer molecules per million molecules of dry air. For example, the methane mole fraction is 0.000002, which converts to 0.000000088 kilograms, or 5% of that of CO₂.

8. CONCLUSIONS

- Applying thermodynamics to the humid air of the atmosphere shows the Sun is always the primary control of Earth's temperature.
- Applying thermodynamics to CO₂ in the atmosphere shows it causes a negligible tiny increase in warming by the increase in enthalpy (heat content).
- When the level of CO₂ was about 4,000 ppm about 600 million years ago, the temperature would have been 0.00487°C above that of today. This amount is too small to measure. However, with its natural variability, the Sun controlled the Earth's temperature at this time and beyond.

- The robust methodology of this study is a good tool for climate research. It opens up a new approach to climate research with convenient access to more than three million weather stations.

ACKNOWLEDGEMENTS

Several people have helped me in various ways to gain the knowledge to write this paper. Some were the University of British Columbia professors who taught about psychrometric charts in the Heating and Ventilating course. Paul Samborsky reviewed my work for many years before publishing it to ensure it is technically correct and there will be no surprises. Howard Hayden, an experienced physicist, often answered my questions, frequently sent me relevant material, and taught me a great deal about the Earth and the atmosphere. Gerald Ratzer continually brings me new knowledge, contacts, and encouragement. There are many others too numerous to mention and many with different points of view.

APPENDIX A: PSYCHROMETRIC CHARTS AND PROGRAMS

Weather stations around the Earth report temperature and relative humidity hourly. A psychrometric chart or program is a helpful method for using the data to calculate the water content of the air as well as other properties such as dew point, enthalpy, and specific volume.

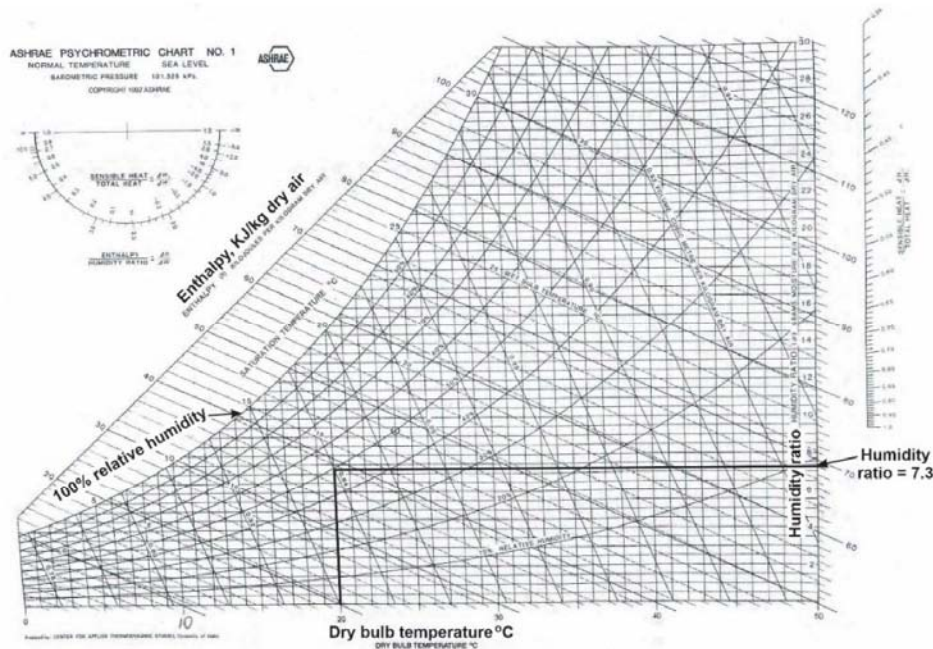


Figure 4: ASHRAE psychrometric chart No. 1 shows how to find the humidity ratio for 20°C and 50% RH.

W. Carrier invented Psychrometric charts in 1904 from previously known information. The charts are used daily by meteorologists and HVAC engineers in building heating and air conditioning systems. Others use them to solve moisture problems. Figure 4 is the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Psychrometric Chart No.1.

The temperature range of ASHRAE Chart No. 1, as in Figure 4, is 0°C to 50°C, the RH range is 0 to 100%, and the humidity ratio is 0 to 30 grams of water per kilogram (kg) of dry air. The black line shows the humidity ratio of 7.3 grams of water per kilogram (kg) of dry air for 20°C and 50% RH. A sea level pressure of 101.325 kPa is the basis for Chart No. 1. In contrast, the Humidair program allows for pressures at different elevations of weather stations [4].

The Humidair psychrometric program is used in this study because it works under an Excel spreadsheet.

There are several descriptions of how to use psychrometric charts on the internet. Reference [25] describes how to use the charts. Humidair is a valuable program when many locations are involved.

APPENDIX B: USING A SMARTPHONE TO ACCESS CURRENT TEMPERATURE AND RELATIVE HUMIDITY

This appendix explains how to replicate the information that leads to the conclusions of this study. Replication of this study is possible from any location with cellphone service.

The Supplementary Information is an Excel spreadsheet with twelve sets of measurements and calculations from Mar 21, 2021, to Feb 21, 2022. This spreadsheet has Humidair behind it. Humidair in Column "O" uses values in columns H, I, M, and N. Changing values in any of these four columns without Humidair installed, changes the Humidity ratios in column P. Protection of the Humidair results is the columns in blue. The setup of the Excel spreadsheet in the Supplementary Information facilitates the start of experiments.

Required are:

1. A smartphone with AccuWeather installed. The author uses an LG K410 smartphone.
2. Microsoft Excel spreadsheet or equivalent.
3. A Humidair psychrometric program or ASHRAE psychrometric chart No. 1.
1. **Smartphone:** Learn how to add the weather station locations in Table 1. Learn how to switch between screens to find the current temperature, RH, local date, and local time. AccuWeather is updated hourly. Recording 20 locations in 15 minutes and checking is within the hourly update schedule. So all measurements are at the same time, i.e., simultaneously.
2. **Excel spreadsheet:** Set up a spreadsheet as in the Supplementary Information. From a psychrometric chart, such as Figure 4, find the humidity ratio on the right-hand axis using the temperature along the bottom and the RH value on the appropriate curve. For temperatures from 0°C to -50°C, use the Humidair program.

To plot the results, insert one of the scatter charts in Excel. For more information about plotting in Excel, ask the relevant question on Google.

3. **Humidair psychrometric program:** Purchase and install Humidair under Excel. Set up a spreadsheet as in Supplementary Information. When you enter the temperature and RH, the humidity ratio in column P will calculate. If you change any weather station locations, you must change the elevation and pressure. The elevation, latitude, and longitude are available from Google Earth.

The Humidair formula is in column J: Humidair (D1, E1, H1, I1), where D1 is the temperature in °C, E1 is RH %, and H1 is pressure in bar. W is the code for a kg of water per kg dry air. Column P is column M multiplied by 1,000.

4. **Changing locations:** Changing weather stations requires changing the elevation and the pressure. Use the Engineering ToolBox formula to calculate pressure: $p = 101325 (1 - 2.25577 \cdot 10^{-5} h)^{5.25588}$ where h = elevation in meters and p = Pascals, Pa. Convert to bar: 1 bar = 100,000 Pa.
5. **Specific data points:** For information about a specific data point, go to the Supplementary Information and access the graph "Temp vs. HumRat." Place the cursor on the point of interest to see the month, temperature, and humidity ratio. Go to the chart "21st of the month". Find the point on the appropriate sheet for the month. There are eight graphs of plots accessed along the bottom of the screen. The spreadsheet title is "21st of the month".
6. **Length of time for recording data:** The data recording for this study occurred over a year. But, much less time also gives good results. For example, Figure 5 shows the results of 400 points recorded at six-hour intervals over five days from Jan 30 to Feb 3, 2022. The points are more to the low-temperature part of the figure because Feb 1 is often North America's coldest part of the year.

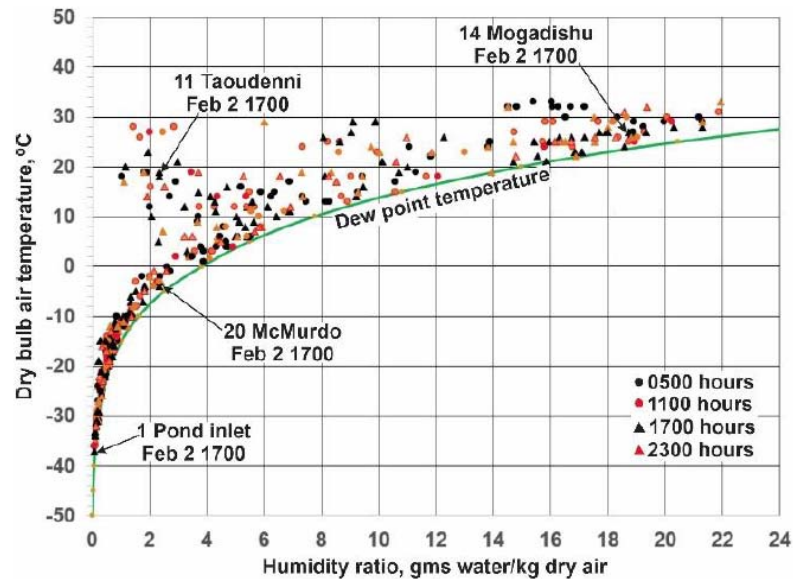


Figure 5: Dry bulb temperature versus humidity ratio for Jan 30, 2022, to Feb 3, 2022, at intervals of approximately six hours for 400 points.

SUPPLEMENTAL MATERIALS

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

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