2022 HiMCM
Problem B: CO_2 and Global Warming

Prior to the Industrial Revolution, carbon dioxide (CO2) in the atmosphere was consistently around 280 parts per million (ppm). The concentration of CO2 in the atmosphere reached 377.7 ppm in March of 2004, resulting in the largest 10-year average increase up to that time.[1] According to scientists from National Oceanographic and Atmospheric Administration (NOAA) and Scripps Institution of Oceanography (SIO) the monthly mean CO2 concentration level peaked at 421 ppm in May 2022.[2] An Organisation for Economic Co-Operations and Development (OECD) report predicts a CO2 level of 685 ppm by 2050.[3]

Photo credit: pixabay.com

The editors of *Scientific Today* magazine have asked your team to address these claims of the current reported and future predictions of CO2 concentration levels. They provided two data sets (**CO2 Data Set 1** & **Temps Data Set 2**) to assist in your research.

Requirements

1. Do you agree with CO2 level claims? Use **CO2 Data Set 1** to analyze CO2 changes.

a. Do you agree that the March 2004 increase of CO2 resulted in a larger increase than observed over any previous 10-year period? Why or why not?
b. Fit various (more than one) mathematical models to the data to describe past, and predict future, concentration levels of CO2 in the atmosphere.
c. Use each of your models to predict the CO2 concentrations in the atmosphere in the year 2100. Do any of your models agree with claims and predictions that the CO2 concentration level will reach 685 ppm by 2050? If not by 2050, when do your models predict the concentration of CO2 reaching 685 ppm?
d. Which model do you consider most accurate? Why?

2. What's the relationship between temperature and CO2? Many scientists think that there is a relationship between warming global temperatures and the concentration of CO2 in the atmosphere. Use your work in part 1 and **Temps Data Set 2** to assist in your comparison of land-ocean temperatures and CO2 concentration levels.

a. Build a model to predict future land-ocean temperatures changes. When does your model predict the average land-ocean temperature will change by 1.25°C, 1.50°C, and 2°C compared to the base period of 1951-1980?
b. Build a model to analyze the relationship (if any) between CO2 concentrations and land-ocean temperatures since 1959. Explain the relationship or justify that there is no relationship.
c. Extend your model from part 2.b. into the future. How far into the future is your model reliable? What concerns, if any, do you have with your model's ability to predict future CO2 concentration levels and/or land-ocean temperatures?

3. Prepare a non-technical article (1 page maximum) for *Scientific Today* to explain in your team's findings and possible recommendations for the future.

Your PDF solution of no more than 25 total pages should include:

- One-page Summary Sheet.
- Table of Contents.
- Your complete solution.
- One-page non-technical Article.
- References list.

Note: The HiMCM Contest has a 25-page limit. All aspects of your submission count toward the 25-page limit (Summary Sheet, Table of Contents, Reference List, Article, and any Appendices).

Attachment

2022_HiMCM_Data.xlsx

Sheet 1: CO2 Data Set 1
Sheet 2: Temps Data Set 2

References

[1] National Oceanographic and Atmospheric Administration. NOAA Earth System Research Laboratory. (2022, October). *Trends in atmospheric carbon dioxide* [Internet]. https://gml.noaa.gov/ccgg/trends/data.html.

[2] National Oceanographic and Atmospheric Administration. NOAA Research News & Features. (2022, June 3). *Carbon dioxide now mare than 50% higher than pre-industrial levels* [Internet]. https://www.noaa.gov/news-release/carbon-dioxide-now-more-than-50-higher-than-pre-industrial-levels.

[3] Organisation for Economic Co-Operations and Development. (2012). *The OECD environmental outlook to 2050* [Internet]. https://www.oecd.org/env/cc/Outlook%20to%202050_Climate%20Change%20Chapter_HIGLIGHTS-FINA-8pager-UPDATED%20NOV2012.pdf.

CO2 Data Set 1: Annual month of March averages of CO2 expressed as a mole fraction in dry air, micromole/mol, abbreviated PPM (parts per million) derived from continuous air samples for the Mauna Loa Observatory, Hawaii, U.S.A.

Year	PPM		Year	PPM		Year	PPM
1959	315.98		1980	338.76		2001	371.32
1960	316.91		1981	340.12		2002	373.45
1961	317.64		1982	341.48		2003	375.98
1962	318.45		1983	343.15		2004	377.7
1963	318.99		1984	344.87		2005	379.98
1964	319.62		1985	346.35		2006	382.09
1965	320.04		1986	347.61		2007	384.02
1966	321.37		1987	349.31		2008	385.83
1967	322.18		1988	351.69		2009	387.64
1968	323.05		1989	353.2		2010	390.1
1969	324.62		1990	354.45		2011	391.85
1970	325.68		1991	355.7		2012	394.06
1971	326.32		1992	356.54		2013	396.74
1972	327.46		1993	357.21		2014	398.81
1973	329.68		1994	358.96		2015	401.01
1974	330.19		1995	360.97		2016	404.41
1975	331.13		1996	362.74		2017	406.76
1976	332.03		1997	363.88		2018	408.72
1977	333.84		1998	366.84		2019	411.66
1978	335.41		1999	368.54		2020	414.24
1979	336.84		2000	369.71		2021	416.45

Data Source Credit: National Oceanographic and Atmospheric Administration (NOAA) GML Data and Scripps Institution of Oceanography (SIO).
https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_annmean_mlo.txt.

Temps Data Set 2: Global annual mean surface-air temperature change in degrees Celsius based on land and ocean data compared to the temperature mean of the base period 1951-1980. For example, in 2021, the global land and sea temperature was 0.84°C above the temperature mean of the base period of 1951-1980.

Year	Degrees C		Year	Degrees C		Year	Degrees C
1958	0.06		1980	0.26		2002	0.63
1959	0.03		1981	0.32		2003	0.62
1960	-0.03		1982	0.14		2004	0.53
1961	0.06		1983	0.31		2005	0.67
1962	0.03		1984	0.16		2006	0.63
1963	0.05		1985	0.12		2007	0.66
1964	-0.2		1986	0.18		2008	0.54
1965	-0.11		1987	0.32		2009	0.65
1966	-0.06		1988	0.39		2010	0.72
1967	-0.02		1989	0.27		2011	0.61
1968	-0.08		1990	0.45		2012	0.65
1969	0.05		1991	0.4		2013	0.67
1970	0.03		1992	0.22		2014	0.74
1971	-0.08		1993	0.23		2015	0.89
1972	0.01		1994	0.32		2016	1.01
1973	0.16		1995	0.45		2017	0.92
1974	-0.07		1996	0.33		2018	0.84
1975	-0.01		1997	0.46		2019	0.97
1976	-0.1		1998	0.61		2020	1.02
1977	0.18		1999	0.38		2021	0.84
1978	0.07		2000	0.39			
1979	0.16		2001	0.53			

Data Source Credit: National Aeronautics and Space Administration Goddard Institute for Space Studies.

- GISTEMP Team, 2022: *GISS Surface Temperature Analysis (GISTEMP), version 4*. NASA Goddard Institute for Space Studies. Dataset accessed 2022-10-18 at data.giss.nasa.gov/gistemp/.
- Lenssen, N., G. Schmidt, J. Hansen, M. Menne, A. Persin, R. Ruedy, and D. Zyss, 2019: Improvements in the GISTEMP uncertainty model. *J. Geophys. Res. Atmos.*, **124**, no. 12, 6307-6326, doi:10.1029/2018JD029522.