

Homework #5

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Problem 1: In this problem, we will build a box model to understand the Earth's carbon cycle based on the framework in Tomizuka 2009. **[10 points]**

1.1 [15 points] Following equation 1-2 (without the buffer effect), build a two-box model to compute the atmospheric CO₂ level in ppm (parts per million) from 1987 to 2004.

Answer: Firstly, data is retrieved from a CSV file using the Pandas 'read_csv' function to acquire the 'gama' parameter from the 'fossil_fuel.csv' file. Then, using the DataFrame's conditional filtering capabilities, specific year data is selected, covering the period from 1987 to 2004. Initial conditions required for the simulation are set based on literature, including carbon concentrations in the atmosphere and ocean surface, along with transfer coefficients. Numerical integration is performed using the Euler's method to compute the variation in carbon dioxide concentration according to the provided differential equations. At each iterative step, the carbon dioxide concentrations in the atmosphere and ocean are updated. Finally, the results are converted to parts per million (ppm) and stored in a list named 'calculation_without_buffer,' while

concurrently displaying the atmospheric carbon dioxide level for each year.

The outcomes are as follows:

年份: 1987,	大气中二氧化碳水平:	348.71	ppm
年份: 1988,	大气中二氧化碳水平:	350.08	ppm
年份: 1989,	大气中二氧化碳水平:	351.47	ppm
年份: 1990,	大气中二氧化碳水平:	352.87	ppm
年份: 1991,	大气中二氧化碳水平:	354.27	ppm
年份: 1992,	大气中二氧化碳水平:	355.62	ppm
年份: 1993,	大气中二氧化碳水平:	356.95	ppm
年份: 1994,	大气中二氧化碳水平:	358.32	ppm
年份: 1995,	大气中二氧化碳水平:	359.75	ppm
年份: 1996,	大气中二氧化碳水平:	361.21	ppm
年份: 1997,	大气中二氧化碳水平:	362.70	ppm
年份: 1998,	大气中二氧化碳水平:	364.15	ppm
年份: 1999,	大气中二氧化碳水平:	365.56	ppm
年份: 2000,	大气中二氧化碳水平:	367.03	ppm
年份: 2001,	大气中二氧化碳水平:	368.57	ppm
年份: 2002,	大气中二氧化碳水平:	370.12	ppm
年份: 2003,	大气中二氧化碳水平:	371.83	ppm
年份: 2004,	大气中二氧化碳水平:	373.69	ppm

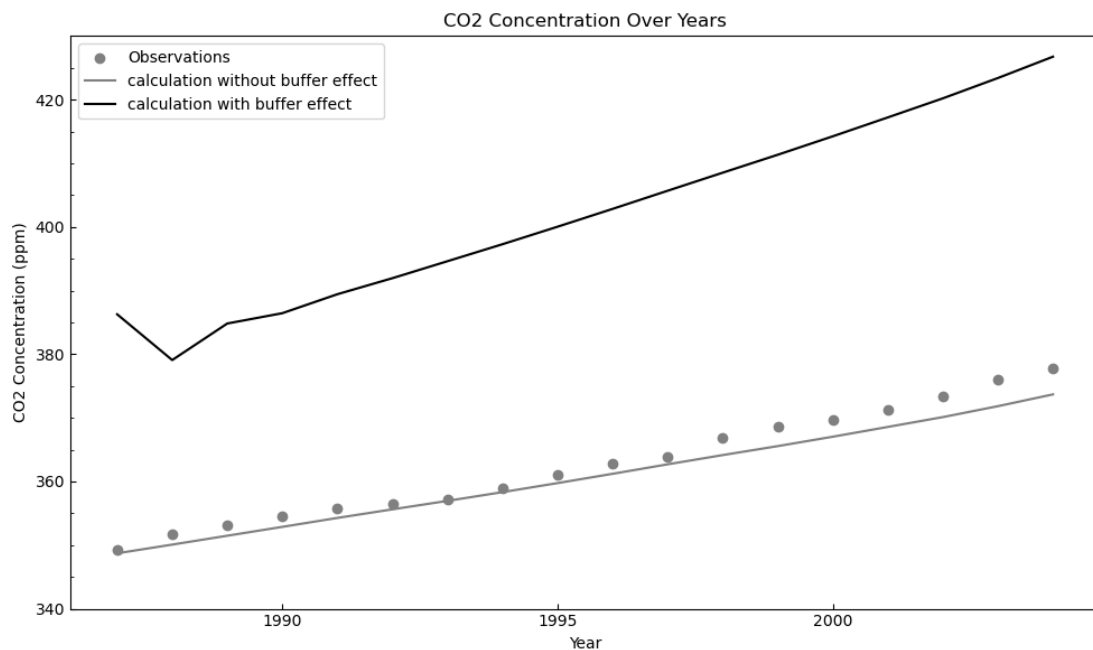
1.2 [20 points] Following equation 3-4 (with the buffer effect), build a two-box model to compute the atmospheric CO₂ level in ppm from 1987 to 2004.

Answer: The approach in section 1.2 follows the same logic as in section 1.1, with the sole distinction being the introduction of a buffering factor in the model. The computed results of this addition are as follows:

年份: 1987, 大气中二氧化碳水平: 386.27 ppm
 年份: 1988, 大气中二氧化碳水平: 379.08 ppm
 年份: 1989, 大气中二氧化碳水平: 384.82 ppm
 年份: 1990, 大气中二氧化碳水平: 386.44 ppm
 年份: 1991, 大气中二氧化碳水平: 389.42 ppm
 年份: 1992, 大气中二氧化碳水平: 391.94 ppm
 年份: 1993, 大气中二氧化碳水平: 394.61 ppm
 年份: 1994, 大气中二氧化碳水平: 397.28 ppm
 年份: 1995, 大气中二氧化碳水平: 400.03 ppm
 年份: 1996, 大气中二氧化碳水平: 402.83 ppm
 年份: 1997, 大气中二氧化碳水平: 405.68 ppm
 年份: 1998, 大气中二氧化碳水平: 408.52 ppm
 年份: 1999, 大气中二氧化碳水平: 411.34 ppm
 年份: 2000, 大气中二氧化碳水平: 414.24 ppm
 年份: 2001, 大气中二氧化碳水平: 417.21 ppm
 年份: 2002, 大气中二氧化碳水平: 420.20 ppm
 年份: 2003, 大气中二氧化碳水平: 423.40 ppm
 年份: 2004, 大气中二氧化碳水平: 426.75 ppm

1.3 [5 points] Based on your results from 1.1 and 1.2, reproduce Figure 2 in Tomizuka (2009) as much as you can.

Answer: The figure is as follows:



[Bonus] [15 points] Following equation 5-13, compute the atmospheric CO2 level in ppm and reproduce Figure 4 in Tomizuka (2009).

Answer: Firstly, using the functions **pd.read_csv()**, **pd.read_excel()**, and **pd.read_csv()**, the data files named `Observations_1750_20000.csv`, `land-use_1750_2005.xls`, and `global_1751_2016.csv` were respectively read. Subsequently, data preprocessing was conducted wherein specific columns were selected and unit conversions were performed using Pandas to align the data with the required format for the model. After defining parameters such as transfer coefficients, gamma, delta, and initial conditions, the code enters a loop. With each iteration, it attempts different beta values (0.38 and 0.5). During the simulation, differential equations and specified parameters were employed to compute the variations in atmospheric CO₂ concentration. Numerical integration via the Euler method was utilized to update the atmospheric CO₂ concentration incrementally from 1751 to 2000. Finally, using the Matplotlib library, the code generated simulated CO₂ concentration curves and scatter plots of observed data, enabling a visual comparison between model simulations and actual observations. The resulting plot demonstrates the fitting of the model to observed data and highlights the impact of different beta values on the model outcomes.

