An Introductory Global CO$_2$ Simulation Model
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On May 10, 2013, the New York Times reported [1] that for the first time in several million years, the CO$_2$ level in the Earth's atmosphere passed 400 ppm (parts per million). Consequently, extreme heat waves, droughts, wildfires, melting glaciers and sea level rise may be a preview of the future, and these unprecedented events will most likely be due to the accumulation of greenhouse gases (GHGs) in the atmosphere, principally CO$_2$ from the burning of fossil fuels.

A mathematical model can be particularly informative and helpful for understanding what is happening. We therefore offer an introductory global CO$_2$ model that gives some key numbers, for example, atmospheric CO$_2$ concentration in ppm as a function of time for the calendar years 1850 (preindustrial) to 2100 (a modest projection into the future). Find more information about the model here: http://www.lehigh.edu/~wes1/co2_cover-1.pdf

The model is based on just seven ordinary differential equations (ODEs) and is therefore intended as an introduction to some basic concepts and as a starting point for more detailed studies. The ODEs are carbon balances for seven reservoirs: upper atmosphere, lower atmosphere, long-lived biota, short-lived biota, ocean upper layer, ocean deep layer, and marine biosphere.

The model also includes ocean chemistry calculations that address acidification with ocean pH typically ranging from 8.2 to 7.8 (pH decreases with increasing acidity). These calculations illustrate some basic numerical procedures, e.g., a Newton solver applied to a fourth order polynomial to calculate ocean pH and spline interpolation to provide additional model outputs. The problem of acidification and CaCO$_3$ dissolution, which has important implications for coral and marine life, as well as ocean CO$_2$ uptake, is addressed by the model.

A basic global warming component has been included based on CO$_2$ buildup in the lower atmosphere but since climate change (warming) is still a controversial and uncertain area, the primary focus is on carbon buildup in the atmosphere and oceans which is being measured quantitatively and is therefore undisputed.

Projected anthropogenic CO$_2$ emissions can be varied to investigate long-term responses (such as atmospheric ppm CO$_2$ and ocean pH). As an application of the model, proposed emissions plans and goals can be evaluated, e.g. plans from various international conferences, environmental groups, and governments.

The CO$_2$ model is available (gratis) as a set of commented routines in Matlab[2] and R[3]. Please direct requests for this model as well as any questions to wes1@lehigh.edu. Upon receipt of a request for the model, we will send the URL and brief download instructions.

References:

[1] http://www.nytimes.com/2013/05/11/science/earth/carbon-dioxide-level-passes-long-feared-milestone.html?pagewanted=all&_r=0
http://www.nytimes.com/interactive/2013/05/10/science/crossing-a-line.html?ref=earth

[2] Matlab is a scientific programming system distributed by the MathWorks, Natick, Ma.

[3] R is an open source scientific programming system that can be downloaded online (at no cost).