An Introductory Global CO2 Model

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On October 4, 2016, the New York Times reported [1] that for the first time in several million years, the CO2 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, i.e., these unprecedented events will most likely be due to the accumulation of greenhouse gases (GHGs) in the atmosphere, principally CO2 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 CO2 model that gives some key numbers, for example, atmospheric CO2 concentration in ppm as a function of time for the calendar years 1850 (preindustrial) to 2100 (a modest projection into the future):

http://www.pdecomp.net/co2Model/overview.php

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 CaCO3 dissolution, which has important implications for coral and marine life, as well as ocean CO2 uptake, is addressed by the model.

A basic global warming component has been included based on CO2 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 CO2 emissions can be varied to investigate long-term responses (such as atmospheric ppm CO2 and ocean pH). As an application of the model, proposed emissions plans and goals can be evaluated, e.g., from various international conferences such as in Paris, December, 2015, environ-

mental groups and governments.

The CO2 model is available (gratis) as a set of commented routines in Matlab [2] and R [3] from the link indicated above. Please direct any questions to wes1@lehigh.edu.

[1] http://www.nytimes.com/2016/10/04/science/atmospheric-carbon-dioxide-400-ppm.html

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 (at no cost) from the Internet.