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Interactive Comment

Interactive comment on "A simple model of the anthropogenically forced CO_2 cycle" *by* W. Weber et al.

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Weber, Lüdeke and Weiss (hereafter WLW15) propose what they describe as a parameter free model for the anthropogenically forced carbon cycle and claim that it accurately calculates atmospheric CO_2 concentrations during the past 150 years. More precisely their two parameters are constrained to match observations. They then use their adjusted model to discuss what would happen when a pulse of CO_2 is injected into the atmosphere. They conclude that the pulse will decrease much more quickly than calculated by other carbon cycle models and be absorbed rapidly into the surface ocean and biosphere. On this basis they claim that excess atmospheric CO_2 will decline much more rapidly when emissions cease (or are limited) than predicted by more sophisticated models described in Joos, 2013 47

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1. General Points

WLW15's model is parsimonious, but as pointed out in the two earlier reviews several of its assumptions are invalid. While such a cavalier treatment can be useful in engineering models whose only purpose is to predict the behavior of a limited range of parameters, it is misleading for characterizing complex system and almost invariably wrong when results are extrapolated beyond the region of fitting.

WLW15 model the interchange between the biosphere (b), the atmosphere (a) and the ocean (s). They calibrate their model against the growth of the atmospheric mixing ratio as measure at Mauna Loa (MLO). They treat the ocean as a single reservoir (swamp ocean), while it is well established that it is strongly stratified. The surface ocean is in direct contact with the atmosphere and rapidly exchanges CO_2 with it on an annual time scale. The exchange between the surface ocean and the thermocline (between 500 and 1000 m) is decadal while exchange with the deep ocean requires centuries. This slower exchange into the commodious (for CO_2) deep oceans explains the long tail of useful carbon cycle models. [Rost and Riebesell, 2004]

Because the interchange with the deep ocean is centennial, and mixing between the atmosphere, the biosphere and the surface annual, the behavior of the atmospheric CO_2 in the annual Mauna Loa record is dominated by the decadal mixing into the thermocline. Thus fitting CO_2 mixing ratios to the MLO record will appear single exponential rather than a sum of exponentials.

In essence fitting to the annual MLO record acts as a filter. If the monthly/weekly MLO record had been used the fast mixing with the surface ocean and the biosphere would have picked out the annual interchange between the atmosphere and the biosphere/surface ocean resulting in a two exponential characteristic. If emissions cease, and Scripps continues to measure CO_2 concentrations for another millennia, yet another, slower exponential decay corresponding to mixing into the deep ocean would be found. Of course, complex carbon cycle models break the system down into even finer detail, and more terms are needed.

Because of this filtering effect the WLW15 model reduces to a one box model of the carbon cycle, many examples of which are discussed in the literature, including in a paper referenced by Weber, et al. Cawley, 2011. Cawley, in criticizing a one box model of Essenhigh reproduces the key result of WLW15, a rapid decrease to zero of a pulse of CO_2 injected into the atmosphere (See Fig. 7 in Cawley), but Cawley also recognizes that the result is spurious.

To quote from Cawley

"The response of the carbon cycle to the injection of a pulse of CO2 can also be reasonably be approximated by a sum of exponentials, with different time-constants reflecting the range of timescale on which the physical mechanisms involved operate. Even uptake of CO_2 by the deep ocean will not fully restore atmospheric carbon dioxide levels back to their pre-industrial equilibrium; anthropogenic emissions have increased the total amount of carbon in the active carbon cycle and a fraction of that additional carbon will remain in the atmosphere after the atmospheric, oceanic and terrestrial reservoirs have fully equilibriated. A full return to pre-industrial levels will require the removal of the carbon from the active carbon cycle via chemical weathering, which permanently sequesters the carbon in the lithosphere. This process takes place on a timescale of tens of thousands of years."

For excess carbon injected into the atmosphere to be totally sequestered into biological materials and to remain there without exchange with the atmosphere would mean that decomposition of biological materials would not be increased by the

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increased amount of material.

2. Conclusion

In short WLW15 may have some validity over the last century to predict the atmospheric concentration CO_2 but for understanding the carbon cycle and for other than business as usual conditions it is worse than not even wrong, it is misleading.

This paper should not be published.

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