Changes in CO$_2$ Through 2100 With and Without a Wind-Water-Solar (WWS) Transition

Comparison of historic (1751 to 2014) observed CO$_2$ mixing ratios (ppmv) from the Siple ice core (Neftel et al., 1994) and the Mauna Loa Observatory (Tans and Keeling, 2015) with GATOR-GCMOM model results (Jacobson, 2014) for the same period plus model projections from 2015 to 2100 for five Intergovernmental Panel on Climate Change (IPCC) scenarios (IPCC, 2000) and three WWS scenarios: an unobtainable case of 100 percent WWS by 2015; a case of 80 percent WWS by 2030 and 100 percent by 2050 (from Figure 9.5), and a less-aggressive case of 80 percent WWS by 2050 and 100 percent by 2100. From Jacobson (2019). Contact Jacobson@stanford.edu.

The model was set up as in Jacobson (2005a) with two columns (one atmospheric box over 38 ocean layers plus one atmospheric box over land). It treated full ocean chemistry in all layers, vertical ocean diffusion with canonical diffusion coefficients, ocean removal of calcium carbonate for shell and rock formation, ocean photosynthesis by phytoplankton and the sinking of its detritus, gas-ocean transfer, and emissions from fossil fuels and land use change. The net carbon sink over land was calculated accounting for time-dependent green-plant photosynthesis, plant and soil respiration, and weathering. No data assimilation or nudging of model results to observations was performed. Preindustrial CO$_2$ was 276 parts per million by volume (ppmv). Fossil-fuel emissions from 1751 to 1958 were from Boden et al. (2011); from 1959 to 2014 were from Le Quere et al. (2015), and for 2015 onward were from three WWS scenarios scaled from 2014 emission and from five individual IPCC scenarios. Land use change emissions per year were held constant at 300 Tg-C/y for 1751 to 1849; from Houghton (2015) for 1850 to 1958; from Le Quere et al. (2015) for 1959 to 2014, from the IPCC (2000) A1B scenario for the WWS cases from 2015 to 2100; and from the individual IPCC scenarios for the remaining cases. Thus, some land use change emissions continued in all scenarios. The average e-folding lifetime of CO$_2$ in the air upon a decrease in CO$_2$, as estimated from the 100 percent WWS (green) curve in the figure, is between about 90 years. This is longer than the data-constrained e-folding lifetime upon an increase of CO$_2$, which has varied over time from about 30 to 60 years since at least 1960 (Jacobson, 2012a). The reason is that, as CO$_2$ is increasing, the air is always supersaturated with respect to the ocean, so the ocean serves as a welcome sink for the CO$_2$. As CO$_2$ begins to decrease, it reaches equilibrium with the ocean, making it difficult for more CO$_2$ in the air to dissolve in ocean surface water. However, photosynthesis by phytoplankton and the sinking of its detritus, ocean shell and rock formation from dissolved CO$_2$, and land removal of CO$_2$ still occur.


