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Radiative forcing and climate response to zeroed emissions of greenhouse gases and aerosols

H. Damon Matthews
Concordia University, Geography, Planning and Environment, Montreal, Canada (dmatthew@alcor.concordia.ca)

Recent research has shown that under zero future emissions of carbon dioxide, surface temperature stabilizes and remains approximately constant for several centuries. This can be understood as a result of declining atmospheric CO_2 levels matched by a declining rate of ocean heat uptake. In other words, the radiation imbalance at the top of the atmosphere is approximately matched by the amount of heat taken up by the ocean, with the result that surface temperature remains constant. This behaviour of the climate system emerges largely because the deep ocean represents the primary sink for both heat and carbon on centennial timescales. However, CO_2 is unique in this respect among anthropogenic radiative forcing agents; consequently, one would not expect a similar climate system response to zeroed emissions of non-CO_2 gases and aerosols. In this paper, I show the radiative forcing and climate response to scenarios of historical followed by zero future emissions of CO_2, non-CO_2 greenhouse gases, and aerosols. Aerosol forcing decreases to zero almost immediately after a cessation of emissions on account of the very short lifetime of tropospheric aerosols; by itself, this would generate a substantial and rapid warming of surface temperatures. However, non-CO_2 greenhouse gas forcing also declines on decadal timescales, driven primarily by the relatively short atmospheric lifetime of methane. This counters a large part of the climate warming from the removed aerosol forcing. As a result, the immediate climate response to zeroed emissions of all radiative forcing agents is a warming of a few tenths of a degree, followed by a gradual cooling that converges with the CO_2-only result on centennial timescales.