Supplement to An Empirical Model of Global Climate: 2. Implications for Future Temperature

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The halocarbon mixing ratio scenarios used in this study are predominantly drawn from the Representative Concentration Pathways (RCP) scenarios (Meinshausen et al., 2011; van Vuuren et al., 2011), with modifications that capture the considerable range of future possibilities not represented by RCP. We use WMO (2011) projections of CFC-11, CFC-12, CFC-113, CCl_4, HCFC-141b, HCFC-142b, Halon 1301, and Halon 2402, rather than projections from RCP, because the WMO (2011) values provide a more accurate description of measured abundances of these species, as illustrated in Fig. S1 for CFC-11. The WMO (2011) and RCP estimates for CFC-11 are in good agreement from 1900 to 2005, but diverge after 2005. WMO (2011) noted that CFC-11 and CFC-12 did not decline as rapidly as once expected because a significant portion of emissions arose from unanticipated, slow release from “banks” (typically foam cells). Emission of certain HCFCs has also been higher than expected at the time the RCP scenarios were devised. Since the projections of future halocarbon mixing ratios from WMO (2011) reflect these new developments, we have opted to use WMO (2011) values in our calculations, even though they have no bearing on our results.

Future emissions of HFCs are highly uncertain (Velders et al., 2009) and this is not represented in the RCP scenarios. HFC-125 is the most critical, in terms of RF of climate. Figure S2 shows future mixing ratios for HCF-125 from the four RCP scenarios, together with mixing ratios and projections from Velders et al. (2009). Mixing ratios from Velders et al. (2009) extend only to 2050; we have extrapolated to 2060 (dashed lines). The projections by Velders et al. (2009) consider improving standards of living in developing countries, especially on the African continent, that will lead to extensive future emissions of HFC-125.

Figure S3 compares the direct RF from halocarbons from the four RCP scenarios (top panel) to the three scenarios we have formed. Our high scenario uses HFC mixing ratios from Velders et al. (2009) (their highest mixing ratios for all HFCs), our low scenario uses HFC mixing ratios from RCP 3−PD (which are the largest among the four RCP scenarios) and our Middle scenario splits the difference between High and Low. We use our High halocarbon scenario with RCP 8.5, our Middle scenario with RCP 6.0 and 4.5, and the Low scenario with RCP 3−PD.

In Section 2.2.5 we state that method used to detrend the AMO has little bearing on this study. Figure S4 is identical to Figs. 7c and 7d, except the AMO has been detrended using a linear regression ($AMO_{Had3\ LIN}$ in the notation of Canty et al., 2012). The use of $AMO_{Had3\ LIN}$ provides a better simulation of the climate record, as this proxy leads to rather good simulation of pre-WWI cooling and WWII heating of the temperature record (Canty et al., 2012). The better fit leads to a slight expansion of set of parameters for which an acceptable fit to the climate record can be obtained. As a result, the range of ΔT_{2053} changes from 0.80 to 2.22°C (Fig. 7d) to 0.65 to 2.38°C (Fig. S4b). The fundamental coupling of NAA RF and γ is present regardless of which AMO index is used.

References

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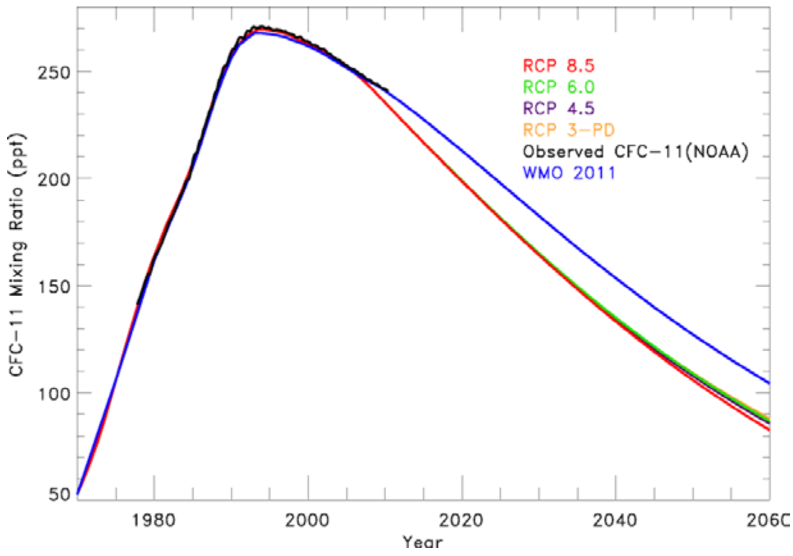

Fig. S1. Global mean mixing ratio of CFC-11 observed by the Halocarbons and other Atmospheric Trace Species (HATS) group of the National Oceanic and Atmospheric Administration (http://www.esrl.noaa.gov/gmd/hats/combined/CFC11.html), the four RCP scenarios, and Table 5A-3 of WMO (2011).

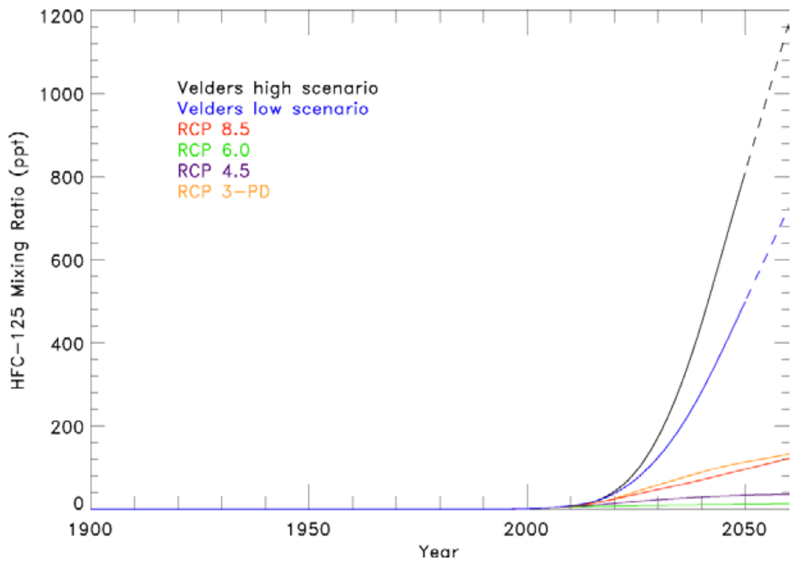

Fig. S2. Global mean mixing ratio of HFC-125 from the four RCP scenarios and from Velders et al. (2009).

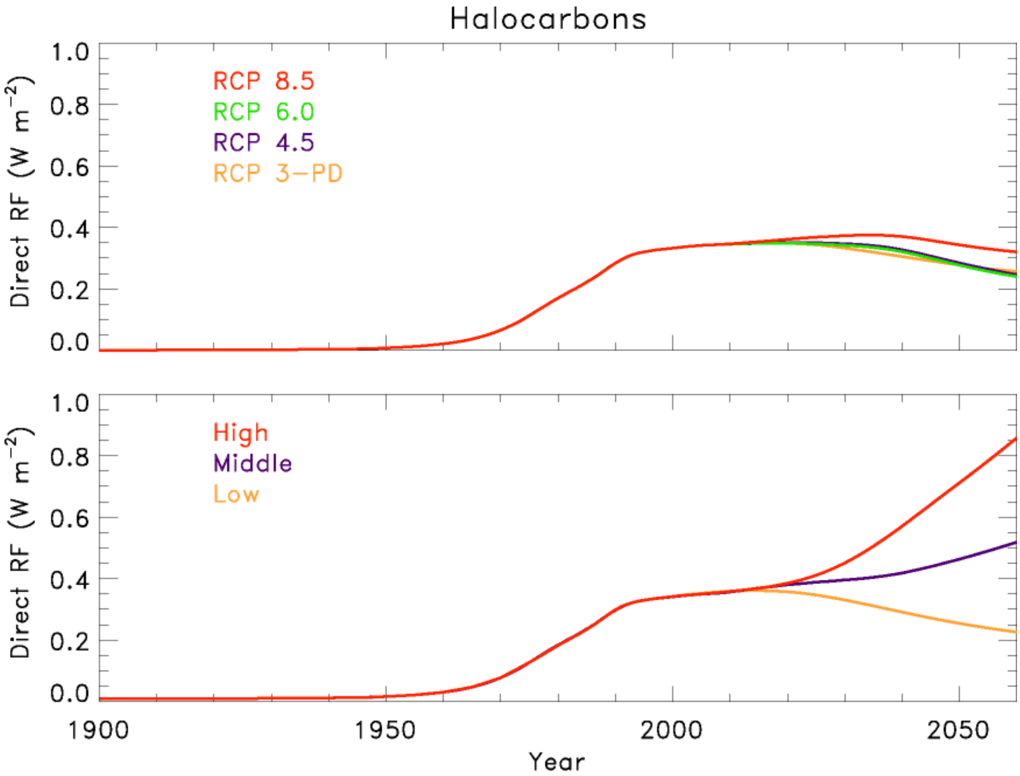

Fig. S3. Direct RF of climate due to halocarbons from the four RCP scenarios (top panel) and from our High, Middle, and Low scenarios. Uncertainty in the future abundance of HFCs, mainly HFC-125, drives the difference in our scenarios.

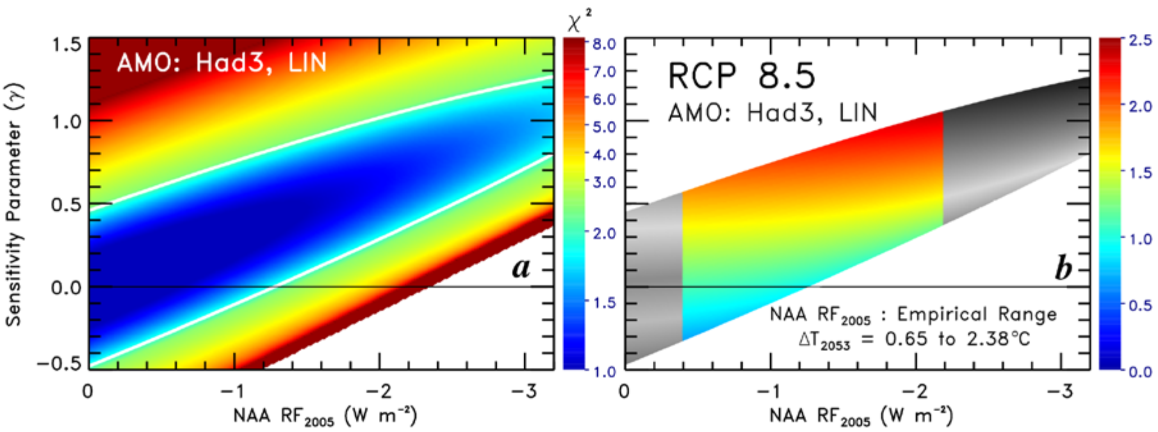

Fig. S4. Direct RF of climate due to halocarbons from the four RCP scenarios (top panel) and from our High, Middle, and Low scenarios. Uncertainty in the future abundance of HFCs, mainly HFC-125, drives the difference in our scenarios.