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A minimal state-dependent impulse-response model of the atmospheric composition and surface temperature response to multi-gas emissions scenarios

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Simple climate models are a powerful tool for the understanding of the climate system. Although at the bottom of the hierarchy of models they remain lightweight tools to study large parameter ensembles within climate science and have applications in a wide range of climate related fields such as economic and policy discussions. However, simple climate models often become unnecessarily attached to the programming language they are written in and unappetising for non-specialists to use.

Here we show that five equations, based on the IPCC AR5 Impulse Response model with the addition of a linear state-dependence of the 100-year integrated impulse response, can reproduce atmospheric composition and surface temperature changes in response to the full range of greenhouse gas emissions. The model is sufficiently simple that it can be written in any iterative program, including languages such as python and more widely used programs such as Excel.

Focussing on CH4, N2O and CO_2, parameters are tuned over a range of multi-gas pathways where emissions and concentrations datasets are available, demonstrating the 5 equations can accurately reproduce the behaviour of more complex models.

We explore the extent to which these 5 equations, with appropriate coefficients and ranges and in specific contexts, are adequate to capture the GMST response to any realistic combination of greenhouse gas emissions and other radiative forcing, without any additional structural complexity. This transparency and simplicity would provide a strong argument in favour of getting a much wider group of modellers to employ the same equation set as a ‘lowest common denominator’ in large assessments. For example, if a single model/set of equations could be used throughout IPCC’s AR6, they would significantly improve the transparency and coherence of the entire assessment.