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Rapid Emulation of Spatially Resolved Temperature Response Functions to Effective Radiative Forcing

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We utilize ideas from signal processing to demonstrate a novel methodology for climate emulation based on the response of the climate system to effective radiative forcing (ERF). While previous work has demonstrated the efficacy of impulse response functions as a tool for climate emulation, these methods are largely non-generalizable to new scenarios and are inaccessible to more general audiences. To remedy this, we propose a generalizable framework for emulation of climate variables such as near-surface air temperature, representing the climate system through the surrogate of spatially resolved impulse response functions. These response functions are derived through the deconvolution of ERF and near-surface air temperature profiles, treating ERF and near-surface air temperature as input and output signals, respectively. Using this framework, new scenarios can be quickly and easily emulated through convolution and other sets of impulse response functions can be derived from any pair of climate variables. We present results from an application to near-surface air temperature based on ERF and temperature data taken from experiments in the sixth phase of the Coupled Model Intercomparison Project (CMIP6). We evaluate the emulator using additional experiments taken from the CMIP6 archive, including the Shared Socioeconomic Pathways (SSPs), demonstrating accurate emulation of global mean and spatially resolved temperature change with respect to the outputs of the CMIP6 ensemble. Global absolute error in emulated temperature averages 0.25 degrees Celsius with a bias ranging from -0.14 to -0.04 degrees Celsius. We additionally show how our emulator can be implemented as a tool for climate education through integration with the En-ROADS platform, providing fast visualizations of spatially resolved temperature change for a number of policy-relevant scenarios. While it is unable to capture state-dependent climate feedbacks, such as the non-linear effects of Arctic sea ice melt in high-warming scenarios, our results show that the emulator is generalizable to any scenario independent of the specific forcings present.