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## Radiative forcing and climate feedbacks explain the cause of the suppressed late 20th century warming in CMIP6 models

Christopher Smith<sup>1,2</sup>, Piers Forster<sup>1</sup>, and Hege-Beate Fredriksen<sup>3</sup>

<sup>1</sup>Priestley International Centre for Climate, University of Leeds, Leeds, UK

<sup>2</sup>International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

<sup>3</sup>Department of Physics and Technology, UiT the Arctic University of Norway, Tromsø, Norway

For the 1960-2000 period, the latest generation of climate models (CMIP6) shows less global mean surface temperature change relative to pre-industrial than that seen in observations. In contrast, the previous generation of models (CMIP5) warmed in line with observations over this period. It has been hypothesised that this suppressed late-20th Century warming seen in CMIP6 is caused by a stronger aerosol effective radiative forcing (ERF) than in CMIP5. We investigate the role that historical ERF plays in historical global mean warming.

To diagnose the historical ERF we determine the climate feedback parameter from regression of top-of-atmosphere energy imbalance against temperature in abrupt-4xCO<sub>2</sub> runs and use the diagnosed climate feedback values in the historical simulations from the same models. We evaluate the historical ERF in 35 CMIP6 and 27 CMIP5 models. We show that this method to estimate ERF is a fairly good approximation to more accurate estimates using atmosphere-only integrations from the Radiative Forcing Model Intercomparison Project (RFMIP). The agreement with RFMIP is best in those models with little or no time dependence (curvature) in their climate feedback parameter. However, the historical ERF estimate can be improved by considering the non-linearity in climate feedbacks. To do this we repeat the process using a three time-constant regression model, showing that this method gives results that are much closer to RFMIP in those models that perform poorly with the one-parameter model.

Under both the one- and three-parameter methods, we show that total historical ERF is lower in CMIP6 than in CMIP5 for 1960-2000. This lower forcing at first appears to explain the differences in warming between the CMIP6 and CMIP5 ensembles. To dive deeper into the contribution to historical forcing we also estimate ERF contributions from greenhouse gases, other anthropogenic forcings (including aerosols), and natural forcing in the subset of CMIP6 and CMIP5 models that performed experiments from the Detection and Attribution Model Intercomparison Project (DAMIP). The causes are a stronger negative aerosol ERF and weaker positive greenhouse gas ERF in CMIP6 compared to CMIP5. However, these forcing differences are amplified by differences in climate sensitivity between the CMIP5 and CMIP6 ensemble, which leads to both a stronger aerosol cooling over 1960-1990 and a stronger greenhouse gas induced warming from 1990 in CMIP6.

