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The effects of constraining large-scale meteorological fields on the stratospheric mean meridional circulation

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This study compares the strength and structure of the stratospheric residual circulation in hind-cast free-running (REF-C1) and specified dynamics (REFC1-SD) Chemistry-Climate Model Initiative (CCMI) simulations for the period 1980-2010. In REFC1-SD, large-scale meteorological fields (typically u, v and T) are constrained towards meteorological reanalysis data. We assess the characteristics of climatological annual mean, seasonal cycle, interannual variability and long-term trends in the stratospheric residual circulation. We find that constraining meteorological parameters in the REFC1-SD runs produces larger intermodel spread in the climatological residual vertical velocity compared to free-running models. However, the interannual variability in tropical upward mass flux shows remarkable consistency across the REFC1-SD simulations in contrast to the free running simulations, which show low temporal covariance. A multiple linear regression (MLR) analysis is performed to account for contributions from volcanic activity, El Niño Southern Oscillation (ENSO), a linear trend and two Quasi-Biennial Oscillation (QBO) terms. The MLR analysis explains a larger fraction of the variance in the tropical upward mass flux timeseries in the nudged simulations compared with the free running simulations. Downward control (DC) principle calculations are performed to diagnose the contributions from resolved waves (EP flux divergence) and parametrized gravity wave drag to the tropical upward mass flux. Mass flux contributions from each of the above wave types are better constrained in the nudged meteorology runs, meaning that a large part of the intermodel spread in upward mass flux cannot be explained by the modelled wave driving. The larger intermodel spread in the climatological residual circulation in the REFC1-SD simulations may be because the models nudge towards different reanalysis datasets and/or because they use different techniques for implementing the nudging. We also calculate the long-term trends in tropical upwelling to estimate the time of emergence of a statistically significant trend in the simulated residual circulation.