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Quantifying the contribution of forcing and three prominent modes of variability to historical climate

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Climate models can produce accurate representations of the most important modes of climate variability, but they cannot be expected to follow their observed time evolution. This makes direct comparison of simulated and observed variability difficult, and creates uncertainty in estimates of forced change. Here we discuss the use of a particle filter data-assimilation technique in a global climate model, that sub-selects members among an ensemble of simulations, to follow the observed Northern Atlantic Oscillation, El Niño Southern Oscillation and Southern Annular Mode, without the use of nudging terms. We investigate the role of these three modes of climate variability, as pacemakers of climate variability since 1781, evaluating where their evolution masks or enhances forced climate trends. Since the climate model also contains external forcings, these simulations, in combination with model experiments with identical forcing but no assimilation, can be used to compare the forced response to the effect of the three modes assimilated and evaluate the extent to which these are confounded with the forced response. The assimilated model is significantly closer than the “forcing only” simulations to annual temperature and precipitation observations over many regions, in particular the tropics, the North Atlantic and Europe. We will show that the NAO variability leads to large multi-decadal trends in temperature, and sea-ice concentration, and that constraining the El Niño–Southern Oscillation reconciles simulated global cooling with that observed after volcanic eruptions.