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Palaeo-conditioning a coupled climate model to reproduce the Holocene greening of the Sahara and the warm poles of the Eocene

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General circulation models (GCMs) often fail to reproduce two key aspects of palaeoclimate states: the Holocene Greening of the Sahara and the warm poles of the Early Eocene. These biases are systematic across many generations of GCMs and appear to be largely independent of model complexity or resolution. Recently, solutions to both problems have been proposed through changes to the 'physics' parameterisations in GCMs. These parameterisations are employed to approximate aspects such as clouds, convection and turbulence that are too complex or fine-scale to be represented directly. In this work we employ a perturbed parameter ensemble of coupled GCM simulations that samples uncertainty in these aspects for the pre-industrial, mid-Holocene and early Eocene. Our aim is to evaluate whether one model can reproduce two independent palaeoclimate states satisfactorily and thereby improve the performance of the model for future and other times in the past. We use the coupled GCM HadCM3B and perturb 19 model parameters relating to atmospheric convection, clouds, the land-surface and ocean mixing across >1000 ensemble members. We then use a statistical emulator to learn from the ensemble and palaeo-condition the parameter values based on constraints from observed climatology and mid-Holocene and Eocene climate reconstructions. We examine the compatibility of the two palaeoclimate states in terms of their optimal parameter values and evaluate whether the model can produce the Holocene green Sahara given different assumptions on the contribution of summer (monsoon) and/or winter (stormtrack) rainfall increases. Our results constitute a step towards a fully palaeo-conditioned GCM which can more reliably simulate out-of-sample past or future climate states.