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Modelling the interactions between vegetation and climate from the Cretaceous to the Eocene

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The climates during the Cretaceous (∼144 to 66 Ma) and the early Eocene (∼56 to 48 Ma) were much warmer than the present day. Atmospheric CO_2 levels for these past climates have a large uncertainty associated with them, but were possibly as high as 2000 to 3000 ppm for the early Eocene (Beerling and Royer, 2011; Lowenstein and Demicco, 2006) and maximum values are thought to range from 800 to 1800 ppm during the Cretaceous (Royer et al., 2012). Current modelling efforts have had great difficulty in replicating the shallow latitudinal temperature gradient indicated by proxy data for these time periods (e.g. Heinemann et al., 2009; Winguth et al., 2010; Shellito et al., 2009). Mechanisms that can result in such a low temperature gradient have not been found (Winguth et al., 2010; Beerling et al., 2011; Sloan and Morrill, 1998), but a contributing factor could be that not all climate feedbacks are included in these models. Vegetation feedbacks have been shown to be especially important (e.g. Otto-Bliesner and Upchurch, 1997; Bonan, 2008) so by including a more accurate representation of vegetation in the climate model, the model-data discrepancies may be reduced.

A fully coupled atmosphere-ocean GCM, HadCM3L, coupled to a dynamic global vegetation model (TRIFFID), was used to simulate the climate and the predicted vegetation distributions for and the early Eocene and 12 different time slices representing different ages throughout the Cretaceous at 4x pre-industrial CO_2. The only difference in the way these simulations were set up are different boundary conditions that are specific to that time period, e.g. different solar constants and paleogeographies. This allows a direct comparison between the time slices. We present the changes in climate, and therefore vegetation, during the Cretaceous due to changes in these boundary conditions alone, with a focus on Antarctica.

Additional Eocene simulations were also carried out with a) fixed globally-uniform vegetation and b) a prescribed vegetation distribution as predicted by the TRIFFID model, but with TRIFFID turned off i.e. the vegetation distribution was fixed, not dynamic. All three Eocene simulations were also run for 2x pre-industrial CO_2, allowing the effects of changing CO_2 on climate and vegetation to be analysed. We present the effects of different vegetation representations included in a GCM on the early Eocene climate. In addition, climate sensitivity and sensitivity of vegetation to atmospheric CO_2 concentration during the early Eocene are investigated. Modelled vegetation types are compared to fossil data to evaluate the performance of TRIFFID for these paleoclimate simulations.