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Simulating Quaternary African Environments and the Green Sahara through dynamic coupling of Land Surface and Atmospheric models

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Paleoclimate records from Late Quaternary Africa imply rapid and spatially complex shifts between wet and dry conditions. There is abundant evidence that during numerous incursions in the past the extent of deserts, lakes and rivers is not static. In this work we use an asynchronously coupled atmosphere and vegetation model to investigate our current ability to model Quaternary Africa. We iterate the vegetation scheme BIOME with the Hadley Centre model and explore the changing relationship between African vegetation and climate over the last deglaciation.

During the last deglaciation large amplitude perturbations of the African climate occurred, linked to orbitally forced changes in monsoon strength. Beginning and ending abruptly 7000 and 4000 years BP, a widespread greening of the Sahara is recorded in numerous paleoclimate archives. This greening represents the largest anomaly in the atmosphere-biosphere system in the last 12,000 years. Atmospheric models alone have failed to reproduce the extent of humidity change. Work by Claussen (1994) and Claussen and Gayler (1997) made large leaps forward by incorporating a dynamic vegetation model into simulations of the African Quaternary. Their work suggests that under some conditions multiple equilibria may exist in the atmosphere-biosphere system, providing a mechanism for rapid change.

In this work we apply a similar method to an extensive suite of time slices from the last glacial maximum to the present. We investigate how the role of surface feedbacks in the climate system change through time by employing the Hadley Centre's atmosphere-only model HadAM3 with the BIOME model of Prentice et al (1992) and consider surface hydrology feedbacks using the surface water scheme HYDRA (Coe 1998). Equilibrium time slices across the deglacation are run for pre-industrial, 3, 6, 9, 12, 15, 18, 21 and 24 kyr B.P. climates. Simulations are started with standard vegetation distributions and repeated with rainforest and desert distributions reversed. This tests the model's ability to find it's own equilibrium from a heavily perturbed system, rather than repeating the prescribed climate.