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Surprising Sensitivities in Simulations of Radiative Convective Equilibrium

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The climate and climate-sensitivity of a global model run in radiative equilibrium is explored. Results from simulations with ECHAM6.3 coupled to a slab ocean and run in a wide range of configurations are presented. Simulations both with and without a parameterised representation of deep convection are conducted for CO_2 concentrations ranging from one eighth of present day values to thirty-two times the present day, and for variations in the solar constant of more than a factor of two. Very long simulations, in some case more than a thousand years, are performed to adequately sample the attractor of the different climate states of the model, and provide robust estimates of the system's climate sensitivity parameter.

For the standard configuration of the model the climate sensitivity progressively decreases from very large values (6-7K) for the coldest climates to well below 1 K for the warmest climates. For very high CO_2 levels (16 and 32 times the present value) fluctuations of globally averaged temperature as large as 10 K arise on decadal time-scales. These fluctuations manifest as quasi-period coolings, driven by large and persistent global scale decks of stratiform low clouds, so that for a period of several years global temperatures drop to levels below the lowest temperatures of the climate with present day values of CO_2. The same configuration of the model has more modest sensitivities when the insolation is reduced, but runaway warming results for small (10%) increases. Simulations without parameterised convection have colder (by roughly 10K) climates and smaller (1K) sensitivities, allowing a stable climate with earth-like temperatures even for insolation much (50%) larger than the present day. Such values of insolation are possible because over a large range of the insolation the climate sensitivity parameter is very near zero. The surprising sensitivities of the system, and the limit-cycle like behaviour of the very CO_2 rich climates, can be traced to modulations of the cloudiness and the planetary albedo. These modulations seem to originate from global scale correlations of the form often associated with convective aggregation.