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Effect of land albedo, CO_2, orography, and oceanic heat transport on extreme climates

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Abstract. Using an atmospheric general circulation model of intermediate complexity coupled to a sea ice – slab ocean model, we perform a number of sensitivity experiments under present-day orbital conditions and geographical distribution to assess the possibility that land albedo, atmospheric CO_2, orography and oceanic heat transport may cause an ice-covered Earth. Changing only one boundary or initial condition, the model produces solutions with at least some ice-free oceans in the low latitudes. Using some combination of these forcing parameters, a full Earth's glaciation is obtained. We find that the most significant factor leading to an ice-covered Earth is the high land albedo in combination with initial temperatures set equal to the freezing point. Oceanic heat transport and orography play only a minor role for the climate state. Extremely low concentrations of CO_2 also appear to be insufficient to provoke a runaway ice-albedo feedback, but the strong deviations in surface air temperatures in the Northern Hemisphere point to the existence of a strong nonlinearity in the system. Finally, we argue that the initial condition determines whether the system can go into a completely ice covered state, indicating multiple equilibria, a feature known from simple energy balance models.

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