Seasonality of Polar Warming in Climates with Very High Carbon Dioxide.

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Observations of warm past climates and projections of future climate change show that the Arctic warms more than the global mean, particularly during winter months. Past warm climates such as the early Eocene had above-freezing Arctic continental temperatures year-round. In this work, we show that an enhanced increase of Arctic continental winter temperatures with increased greenhouse gases is a robust consequence of the smaller surface heat capacity of land (compared to ocean), without recourse to other processes or feedbacks. We use a General Circulation Model (GCM) with no clouds or sea ice and a simple representation of land. The equator-to-pole surface temperature gradient falls with increasing CO2, but this is only a near-surface phenomenon and occurs with little change in total meridional heat transport. The high-latitude land has about twice as much warming in winter than in summer, whereas high-latitude ocean has very little seasonality in warming. A surface energy balance model shows how the combination of the smaller surface heat capacity of land and the nonlinearity of the temperature dependence of surface longwave emission gives rise to the seasonality of land surface temperature change. The atmospheric temperature change is surface-enhanced in winter as the atmosphere is near radiative-advective equilibrium, but more vertically homogeneous in summer as the Arctic land gets warm enough to trigger convection. While changes in clouds, sea ice and ocean heat transport undoubtedly play a role in high latitude warming, these results show that surface-enhanced atmospheric temperature change and enhanced land surface temperature change in winter can happen in their absence for very basic and robust reasons.