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Millennial timescale carbon cycle and climate change in a new Earth system model

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We present a new Earth system model of intermediate complexity (EMIC) with a closed carbon cycle and use it to study global change on the millennial timescale. The model includes a 3D ocean with biogeochemistry, sea-ice, an improved energy-moisture balance atmosphere, and a new land surface physics and carbon cycle scheme. Seasonality and simple parameterisations of ocean thermal expansion and Greenland ice sheet melt are included. Six scenarios are used to span a wide range of plausible total fossil fuel CO_2 emissions (1,100-15,000 GtC) and to explore the effects of burning the same amount of fossil fuel (4,000 GtC conventional resources) at different rates.

By the end of the millennium, CO_2 added to the atmosphere by human activities will have been apportioned between the ocean, atmosphere and land surface with the atmospheric concentration ranging up to 5000ppmv for 15,000 GtC emissions. Global warming approaches 12 degrees C in this scenario. The land surface switches from being a carbon sink to a carbon source with widespread loss of soil carbon and some dieback of South East Asian vegetation. Average ocean surface pH drops from 8.2 to 7, which would severely disrupt marine calcifying organisms. A threshold for net mass loss from the Greenland ice sheet of 2.6 deg. C local warming above pre-industrial is just exceeded for 2,700 GtC total emissions. The rate of melt increases linearly with warming above this threshold. For 15,000 GtC emissions, Greenland melt is almost complete by the end of the millennium, contributing 6m to a total of $>$11m global

sea level rise. The fate of the ocean thermohaline circulation (THC) depends on both the rate and total magnitude of emissions. Emitting 8,000 GtC causes collapse of the THC, accelerated by the addition of Greenland melt water, 1,100 GtC emissions allow recovery and 4,000 GtC emissions hold the circulation at intermediate strength due to a steady input of melt water.