Geophysical Research Abstracts
Vol. 15, EGU2013-544, 2013
EGU General Assembly 2013

Path Dependence of Regional Climate Change

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Path dependence of the climate response to CO_2 forcing has been investigated from a global mean perspective, with evidence suggesting that long-term global mean temperature and precipitation changes are proportional to cumulative CO_2 emissions, and independent of emissions pathway. Little research, however, has been done on path dependence of regional climate changes, particularly in areas that could be affected by tipping points.

Here, we utilize the UVic Earth System Climate Model version 2.9, an Earth System Model of Intermediate Complexity. It consists of a 3-dimensional ocean general circulation model, coupled with a dynamic-thermodynamic sea ice model, and a thermodynamic energy-moisture balance model of the atmosphere. This is then coupled with a terrestrial carbon cycle model and an ocean carbon-cycle model containing an inorganic carbon and marine ecosystem component. Model coverage is global with a zonal resolution of 3.6 degrees and meridional resolution of 1.8 degrees.

The model is forced with idealized emissions scenarios across five cumulative emission groups (1300 GtC, 2300 GtC, 3300 GtC, 4300 GtC, and 5300 GtC) to explore the path dependence of (and the possibility of hysteresis in) regional climate changes. Emission curves include both fossil carbon emissions and emissions from land use changes, and span a variety of peak and decline scenarios with varying emission rates, as well as overshoot and instantaneous pulse scenarios.

Tipping points being explored include those responsible for the disappearance of summer Arctic sea-ice, the irreversible melt of the Greenland Ice Sheet, the collapse of the Atlantic Thermohaline Circulation, and the dieback of the Amazonian Rainforest.

Preliminary results suggest that global mean climate change after cessation of CO_2 emissions is independent of the emissions pathway, only varying with total cumulative emissions, in accordance with results from earlier studies. Forthcoming analysis will investigate path dependence of regional climate change. Some evidence exists to support the idea of hysteresis in the Greenland Ice Sheet, and since tipping points represent non-linear elements of the climate system, we suspect that the other tipping points might also show path dependence.