CLIMATE-CARBON CYCLE INTERACTIONS ON MILLENNIAL TO GLACIAL TIMESCALES AS SIMULATED BY A MODEL OF INTERMEDIATE COMPLEXITY

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By

Laurie Menviel

Thesis Committee:

Axel Timmermann, Chairperson

Yuanhui Li

Niklas Schneider

Richard Zeebe

Greg Ravizza

ABSTRACT

During glacial-interglacial cycles, the atmospheric CO_2 content varied by about 100 ppmv. Although atmospheric CO_2 variations played a central role in shaping glacial-interglacial cycles, their origin still remains elusive. A recently proposed hypothesis argues for a southern hemispheric wind control of orbital-scale CO_2 variability. This hypothesis is tested here using an earth system model of intermediate complexity, LOVECLIM. A series of sensitivity experiments demonstrates that a weakening of the southern hemispheric westerlies leads to reduced upwelling of DIC-rich waters in the Southern Ocean and a reduction of surface ocean pCO_2. However, at the same time less nutrients are upwelled in the Southern Ocean and transported to the eastern basin upwelling zones. This leads to a drop of marine export production and an increase in surface ocean pCO_2. The net result of these counteracting effects is a small drop of atmospheric CO_2 that is insufficient to explain the magnitude of glacial-interglacial CO_2 variability.

Another key feature of glacial periods is the occurrence of northern hemispheric meltwater pulses such as Heinrich event 1 (18 ka ago) and the Younger Dryas (11 ka ago). Originating from instabilities of the major ice-sheets, these freshwater pulses led to disruptions of the Atlantic Meridional Overturning Circulation (AMOC) and impacted climate worldwide. As demonstrated by numerous paleo-proxy records, such events were accompanied by a northern hemispheric cooling that lasted hundreds of years and by associated shifts of the Intertropical Convergence Zones. Using LOVECLIM, it is documented that these climate anomalies led to shifts of the major vegetation zones. Under pre-industrial background conditions, the simulated reduced terrestrial primary productivity leads to a carbon release of 120 GtC. A part of this carbon is taken up by the oceans through increased solubility and deep ocean storage. The resulting atmospheric CO_2 rise of 20 ppmv leads to a net warming of the Southern Ocean and Antarctica. Comparing paleo-climate model simulations with paleo-proxy data, it is found that at least 25% of the Antarctic warming during Heinrich events can be attributed to the vegetation response to an AMOC shutdown.