The Role of Net-Negative CO_2 Emission Scenarios in Stabilizing Earth’s Climate

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Introduction

Recent research has shown that CO_2 induced climate change is irreversible on century to millennium time scales. In order to stabilize global temperatures, not only a reduction in CO_2 emissions is needed, but their complete cessation.

In case of overshoot scenarios, when the pre-determined temperature targets are exceeded, the net-negative emissions technologies that remove CO_2 from the atmosphere provide a solution to reach stabilization of global temperatures in the next few centuries.

The purpose of this research is to examine reversibility of climate system components (temperature, sea level rise) under a set of emission scenarios, which include implementation of net-negative technologies and aim to stabilize global temperature in the long term.

Using the University of Victoria Earth System Climate Model (UVic ESCM) of intermediate complexity (version 2.9), we explore the centennial Earth system response for a range of CO_2 emission scenarios, which consider the implementation of CO_2 net-negative technologies (to remove excess CO_2 from the atmosphere).

Net-Negative CO_2 Emission Technologies

Net-negative emission technologies aim to remove CO_2 from the atmosphere. Existing net-negative CO_2 emission technologies with their cost estimates, using a full life cycle analysis (McGlashan et al., 2012) are presented below:

▪ General Direct CO_2 Capture From the Air	\$155/tCO_2
▪ Artificial trees	\$90/tCO_2
▪ **Biomass Energy with Carbon Capture and Storage (bioCCS)**	**\$59-\$111/tCO_2**
▪ Enhancing natural carbon sinks	\$95/tCO_2
▪ Biochar	\$135/tCO_2

Primary Advantages of net-negative emissions:

- ability to influence the timing of mitigation and postponing the action to the future (Krey & Riahi, 2009)
- reduction in the overall costs of mitigation (Krey & Riahi, 2009)
- “an insurance policy against low-probability high-impact events” (Lackner et al., 2012, p.13156).

Methodology

The model used in this research is the University of Victoria Earth System model of intermediate complexity (ESCM 2.9), described in the ”Model” section (Weaver et al., 2001; Eby et al., 2009). The future CO_2 emission pathways are shown in **Fig.1** and include three types of scenarios (meeting the same cumulative target of 543PgC, which is the amount of cumulative emissions compatible with the 2°C target):

- **HIGH** - high emission peak, followed by net-negative emissions
- **MED** - medium emission peak, followed by net-negative emissions
- **ZERO** –low emission peak, followed by a rapid transition to zero-emission economy; does not include net-negative emissions

The emission data for the historical period (1801-2012), use the fossil fuel and land-use CO_2 emission data from the Carbon Dioxide Information Analysis Centre (CDIAC) database.

The forcing from other non-CO_2 greenhouse gases and sulphate aerosols was also provided for the historical period, and then stabilized at the year-2010 constant value for the future years.

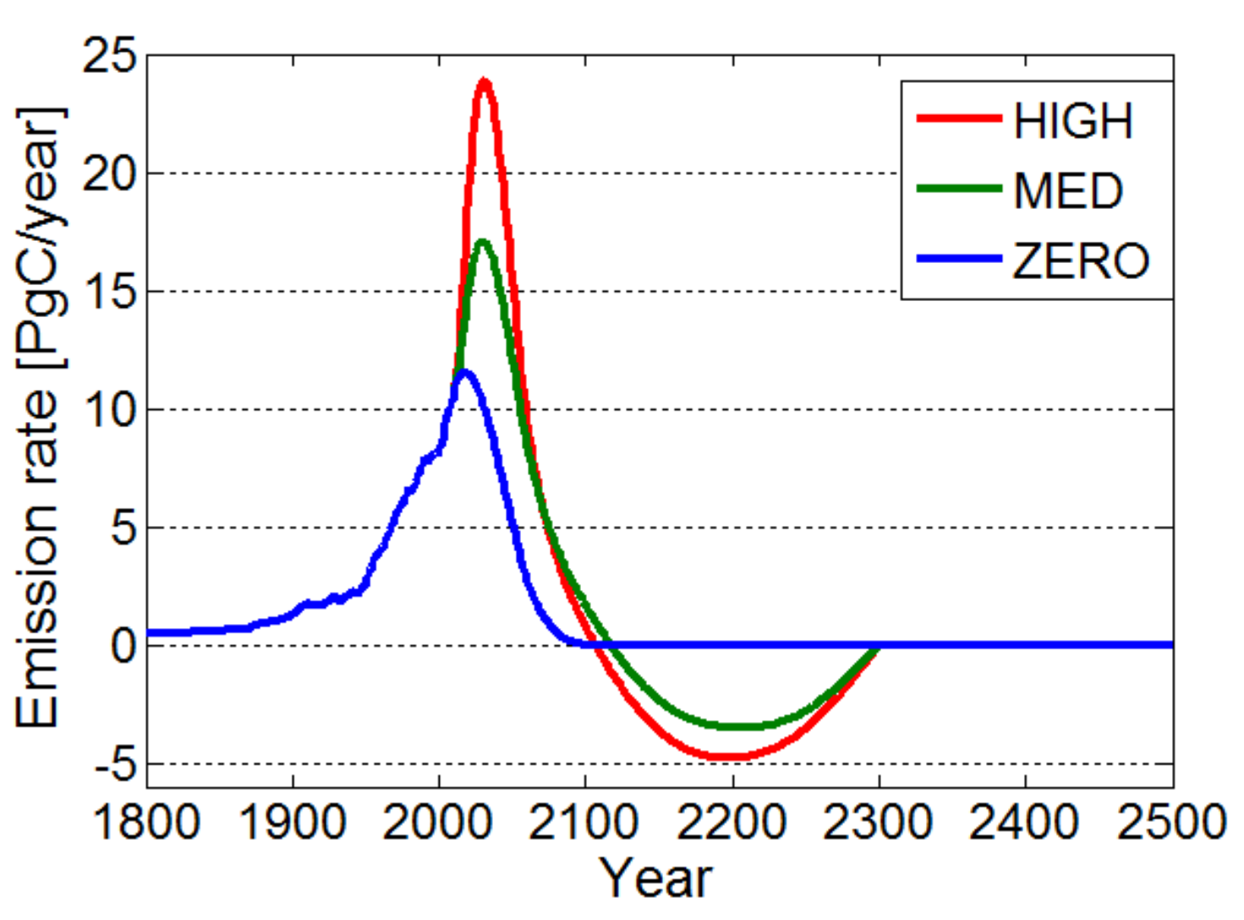


Fig.1. Emission rate in PgC/year.

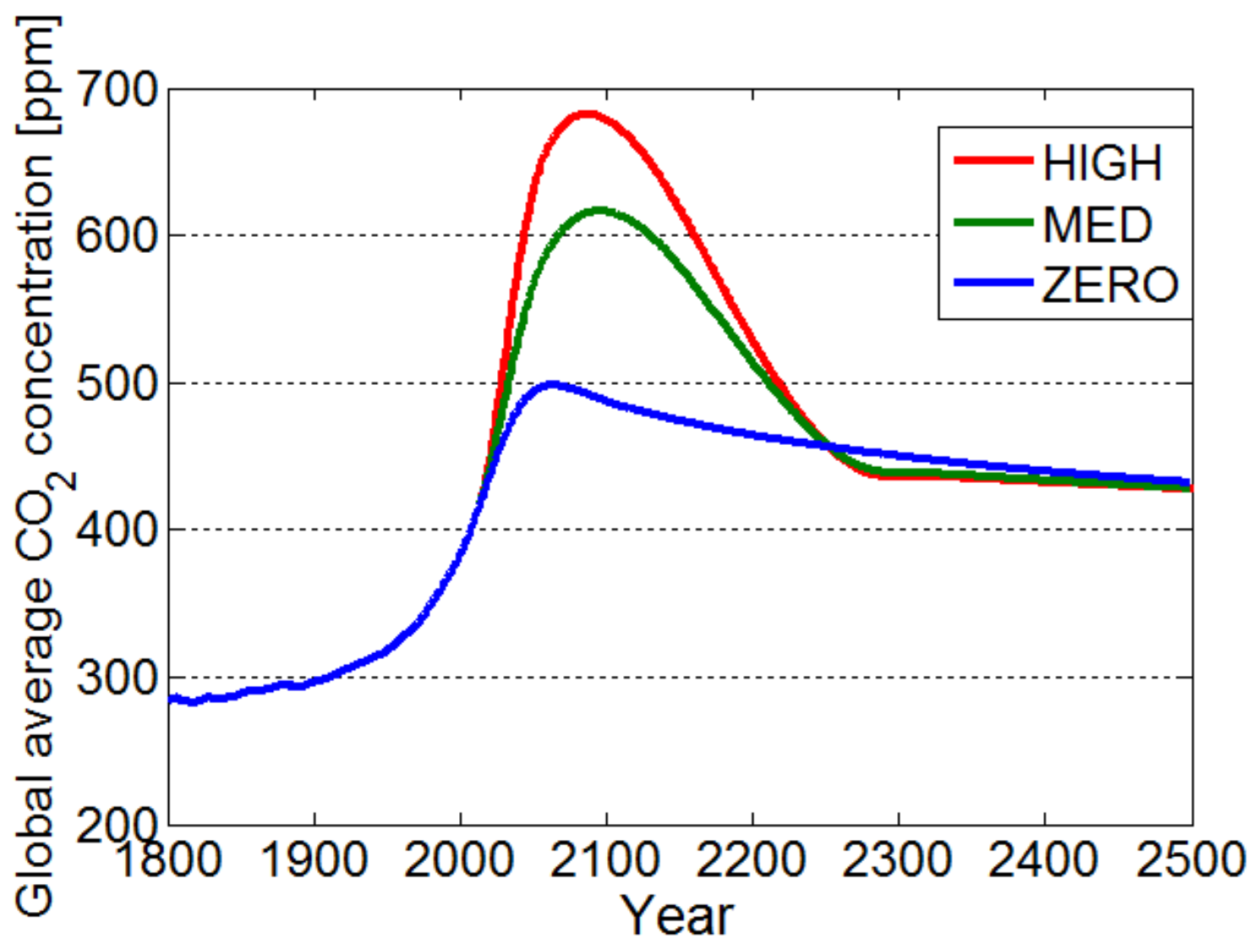


Fig.2. Atmospheric CO_2 concentration.

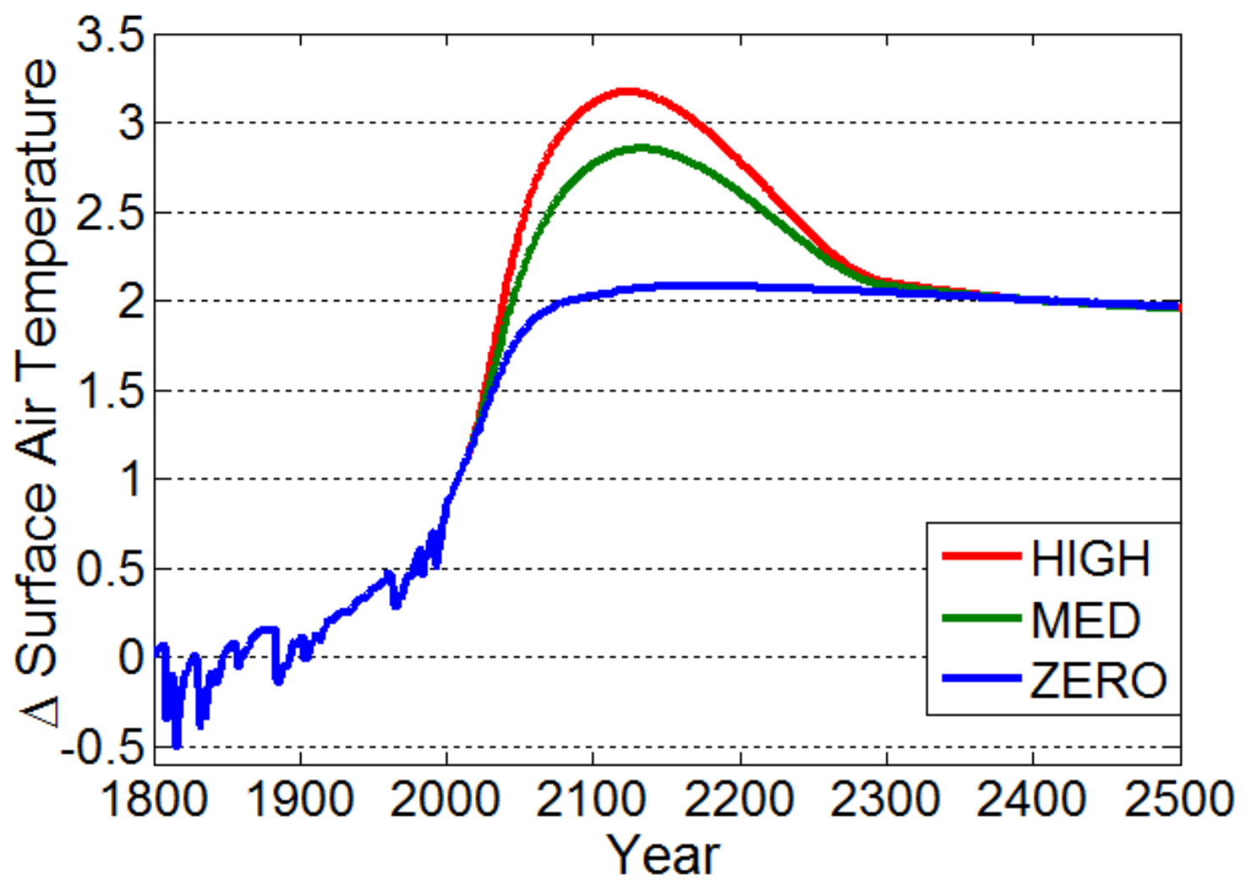


Fig.3. Change in Surface Air Temperature with respect to the year 1805.

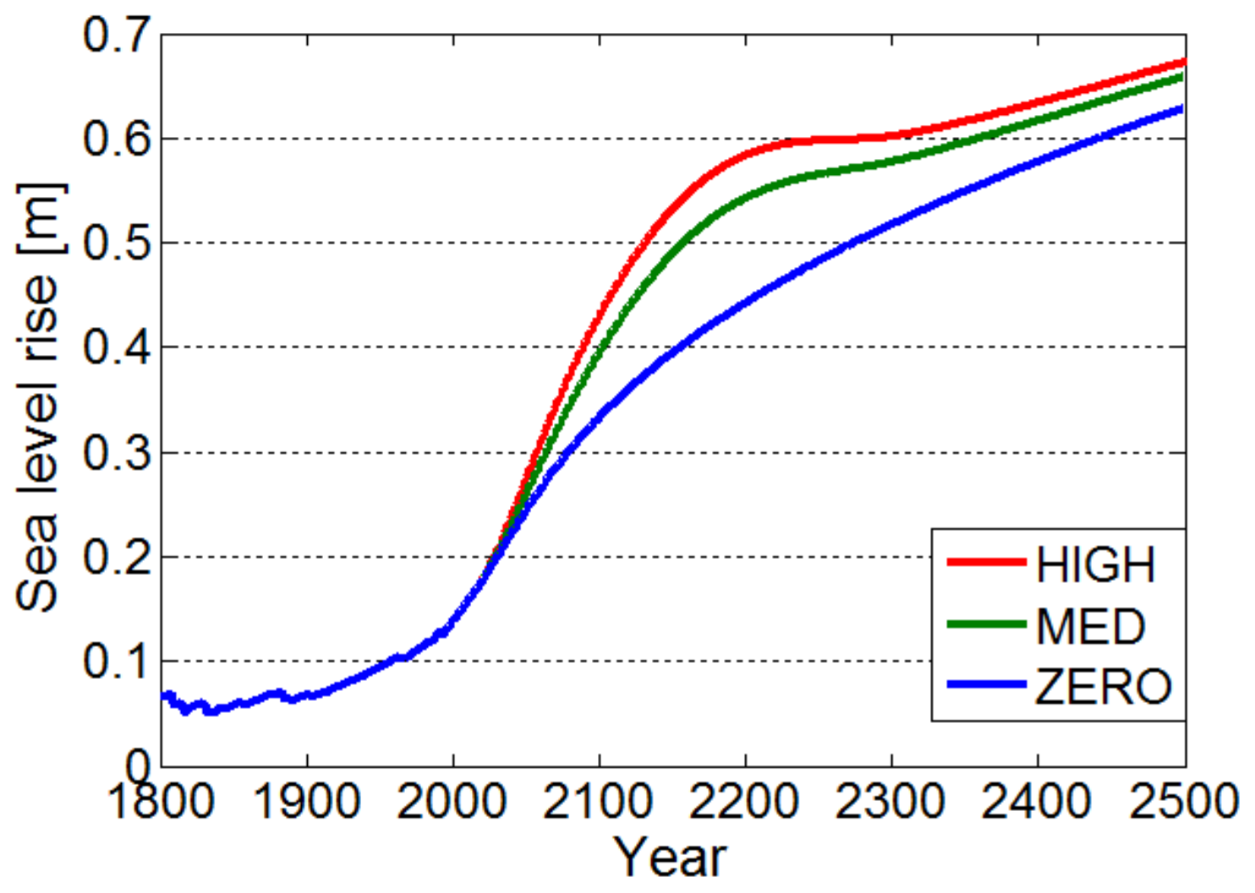


Fig.4. Sea level rise.

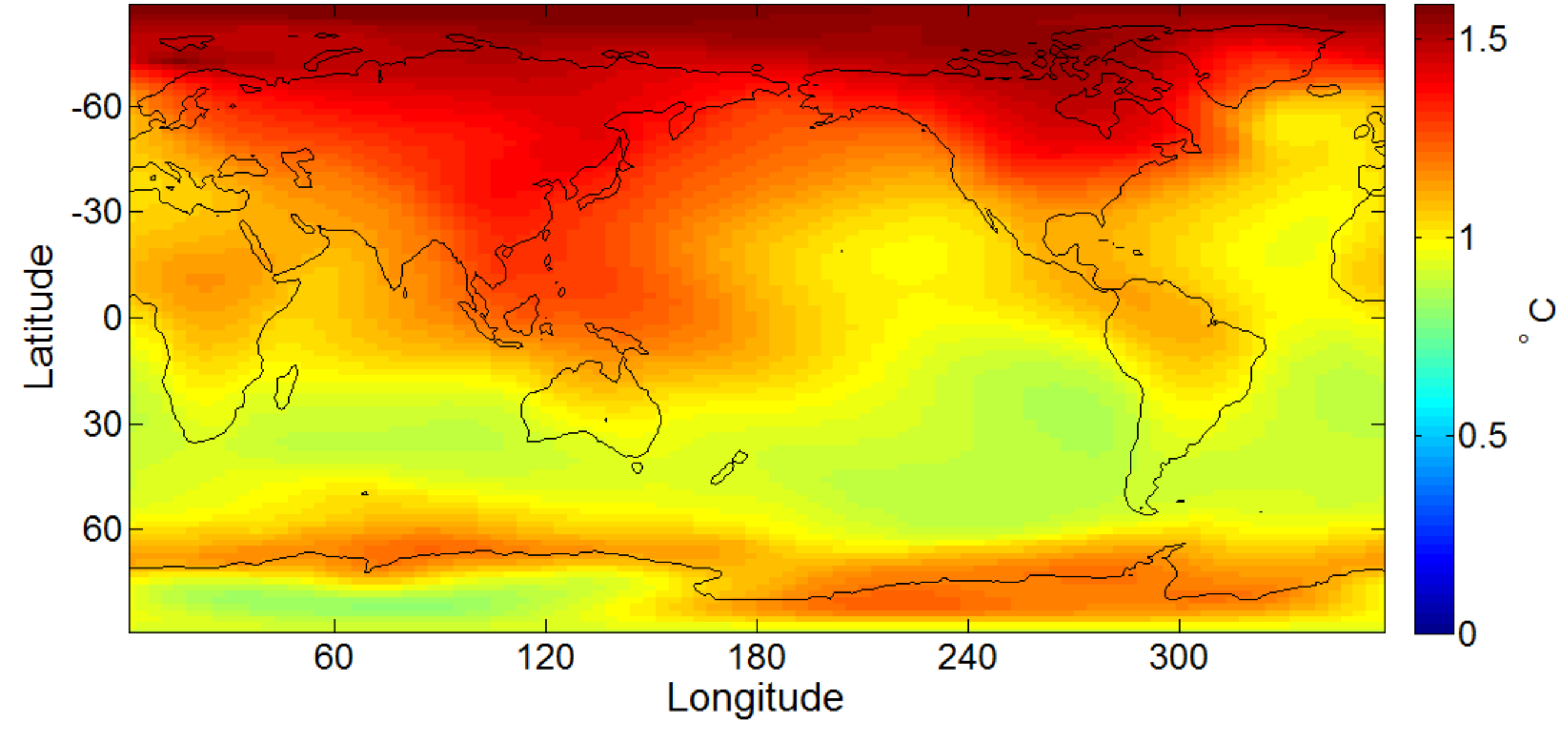


Fig.5. Difference of surface air temperature between HIGH scenario and ZERO scenario at year 2100.

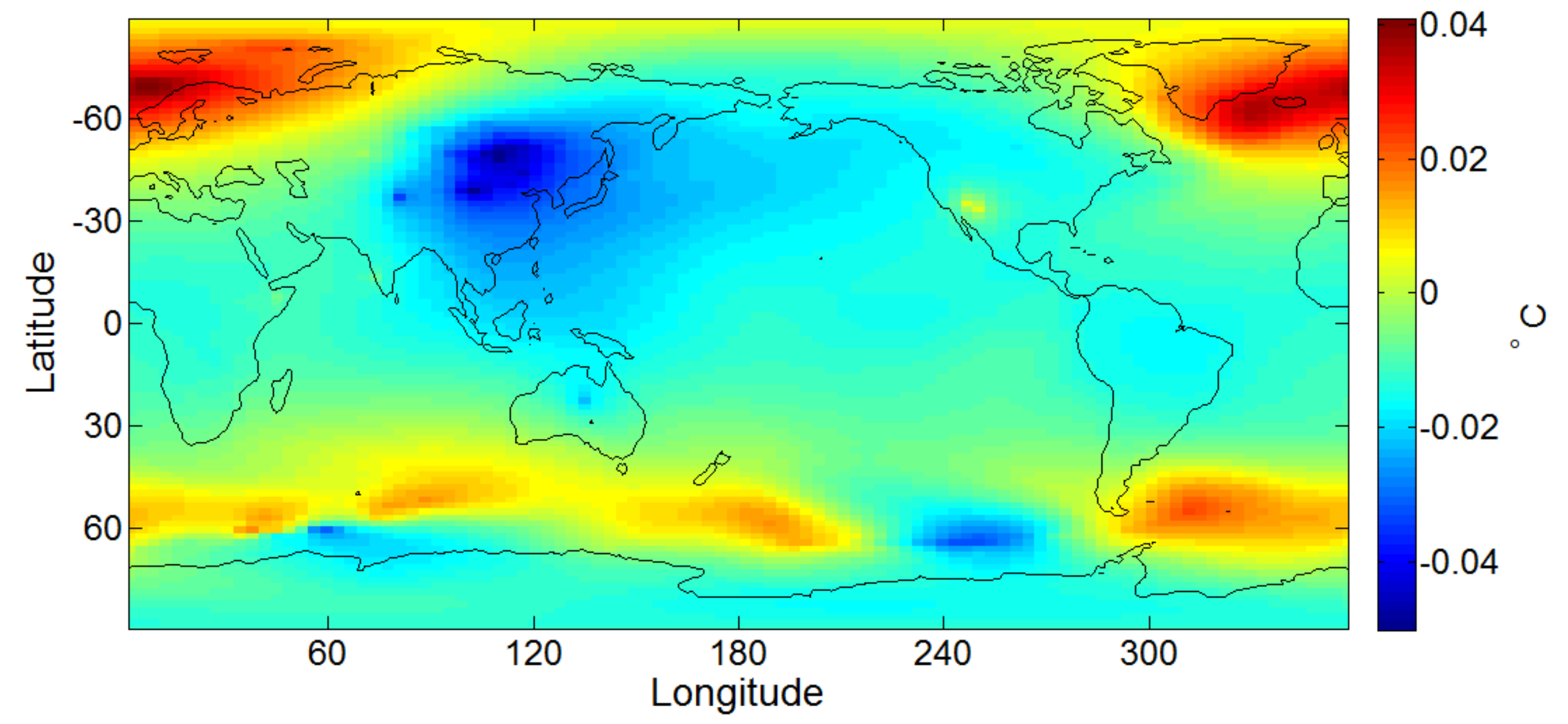


Fig.6. Difference of surface air temperature between HIGH scenario and ZERO scenario at year 2500.

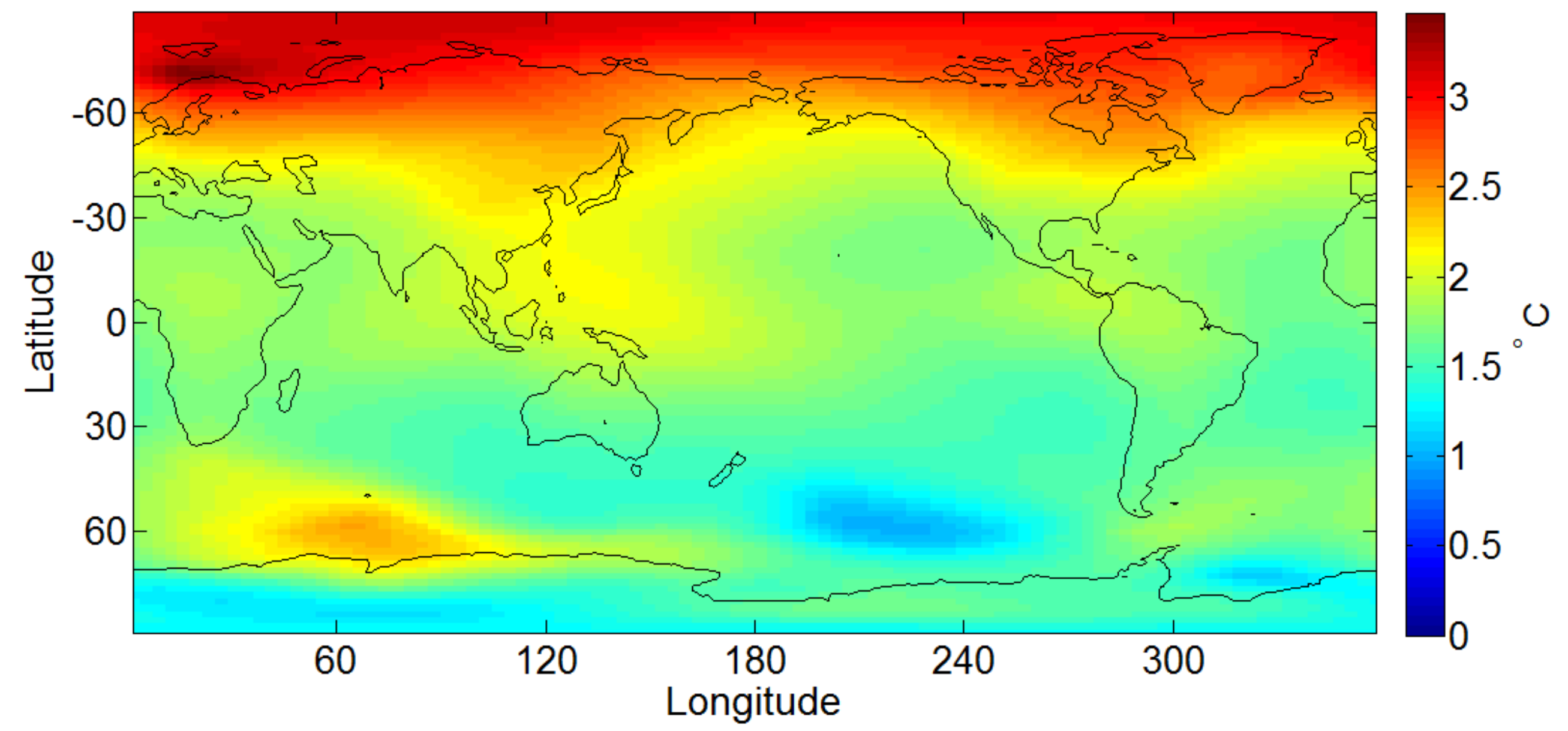


Fig.7. Difference of surface air temperature for HIGH scenario at year 2500, with respect to the year 1900.

Results

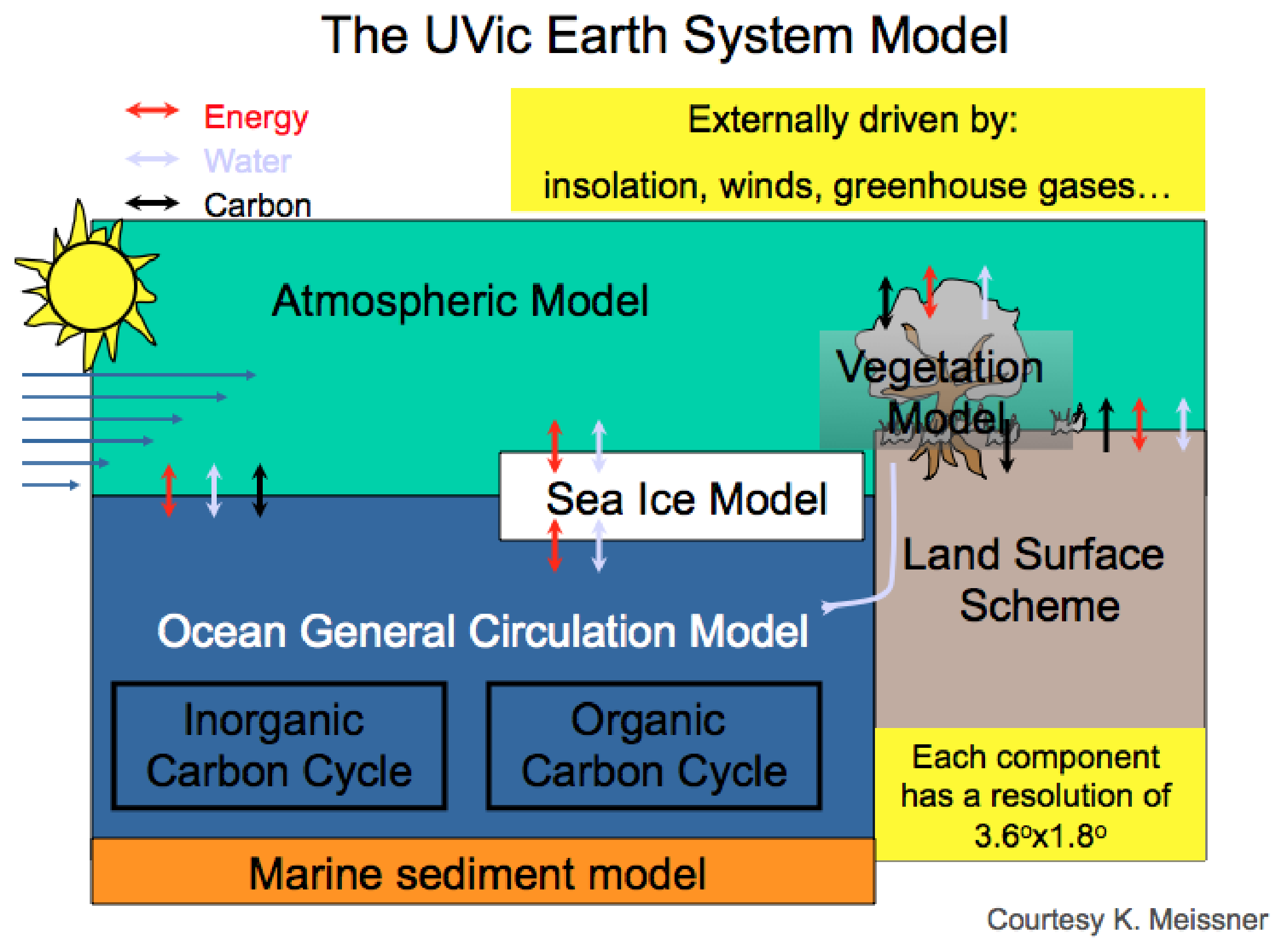
Net-negative CO_2 emissions are successful at restoring the global mean temperature to 2°C above the pre-industrial level on centennial timescales after substantial overshoot (**Fig.3**)

- All three scenarios converge to a warming of 2°C above pre-industrial after CO_2 emissions are zeroed
- At the time of peak warming, the temperature in the HIGH scenario is up to about 1.5°C warmer than in the ZERO scenario (**Fig. 5**)
- Temperature difference between HIGH and ZERO scenarios becomes negligible by 25th century (**Fig. 6**)
- Warming at year 2500 up to 4°C above the pre-industrial temperature level at high northern latitudes (**Fig.7**)
- Sea level continues to rise (**Fig.4**) despite substantial removal of CO_2 from the atmosphere

Subsequently, we calculated the cumulative amount of the net-negative CO_2 emissions applied in each of the scenarios and estimated the cost of each of the scenario, based on the full life-cycle cost analysis for the most cost effective net-negative technology (bioCCS), estimated by the research of McGlashan et al. (2012). There results are shown below:

Scenario	Net-Negative emissions [PgC]	Cost Estimate [trillion \$]
HIGH	621	36.6
MED	438	25.8
ZERO	0	0

Model Used



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