Is there warming in the pipeline?
A multi-model analysis of the zero emission commitment from CO_2

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Introduction

The Zero Emissions Commitment (ZEC) is the change in global mean temperature expected to occur following the cessation of net CO_2 emissions, and as such is a critical parameter for calculating the remaining carbon budget. The Zero Emissions Commitment Model Intercomparison Project (ZECMIP) was established to gain a better understanding of the potential magnitude and sign of ZEC, in addition to the processes that underlie this metric. Eighteen Earth system models of both full and intermediate complexity participated in ZECMIP.

Two sets of idealized CO_2-only experiments were conducted. A-type experiments where emissions follow the 1pctCO2 experiment until to prescribed total is reached and thereafter instantly drop to zero. And B-type experiments where emissions follow a bell-curve trajectory.
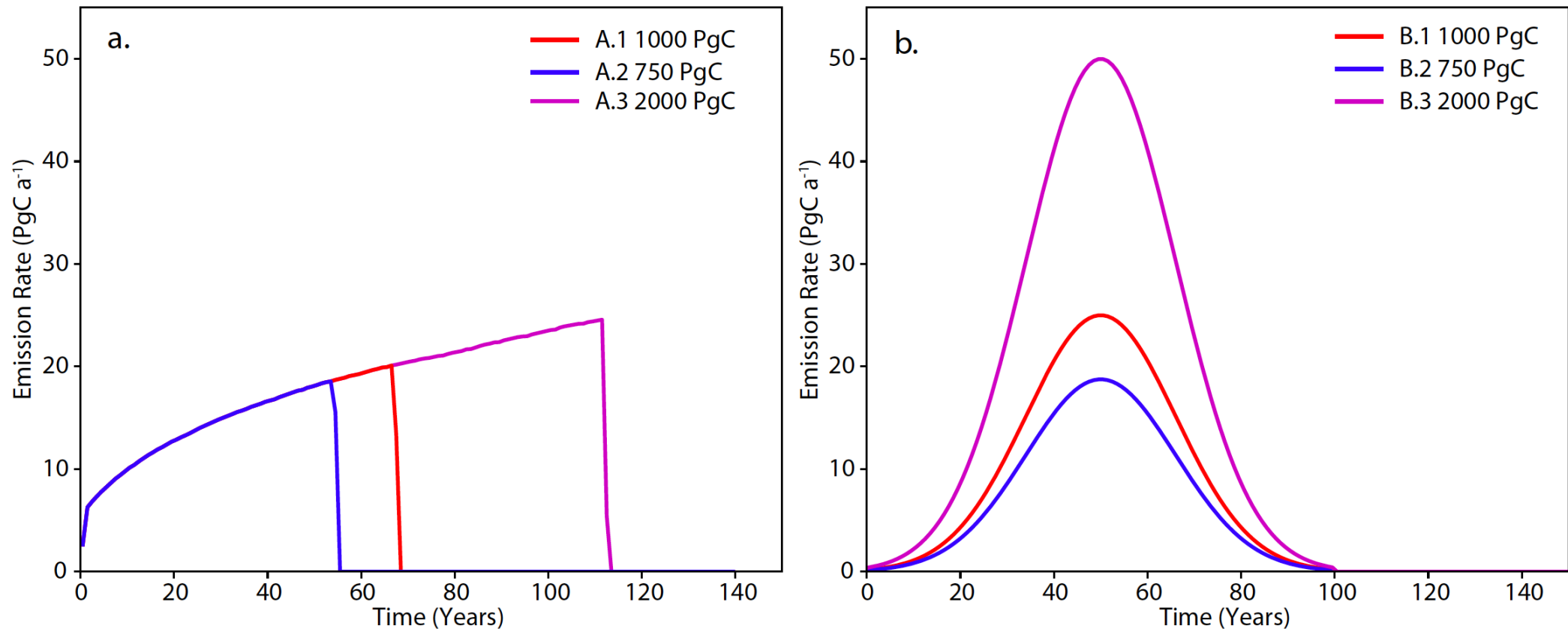
Experiments

Figure 1: a) Diagnosed CO_2 emission for the type A experiments. Type A experiments branch from the 1pct CO_2 experiment when the required emissions total is reached. b) Time series of global CO_2 emissions for bell curve pathways B1 to B3. The numbers in the legend indicate the cumulative amount of CO_2 emissions for each simulation.
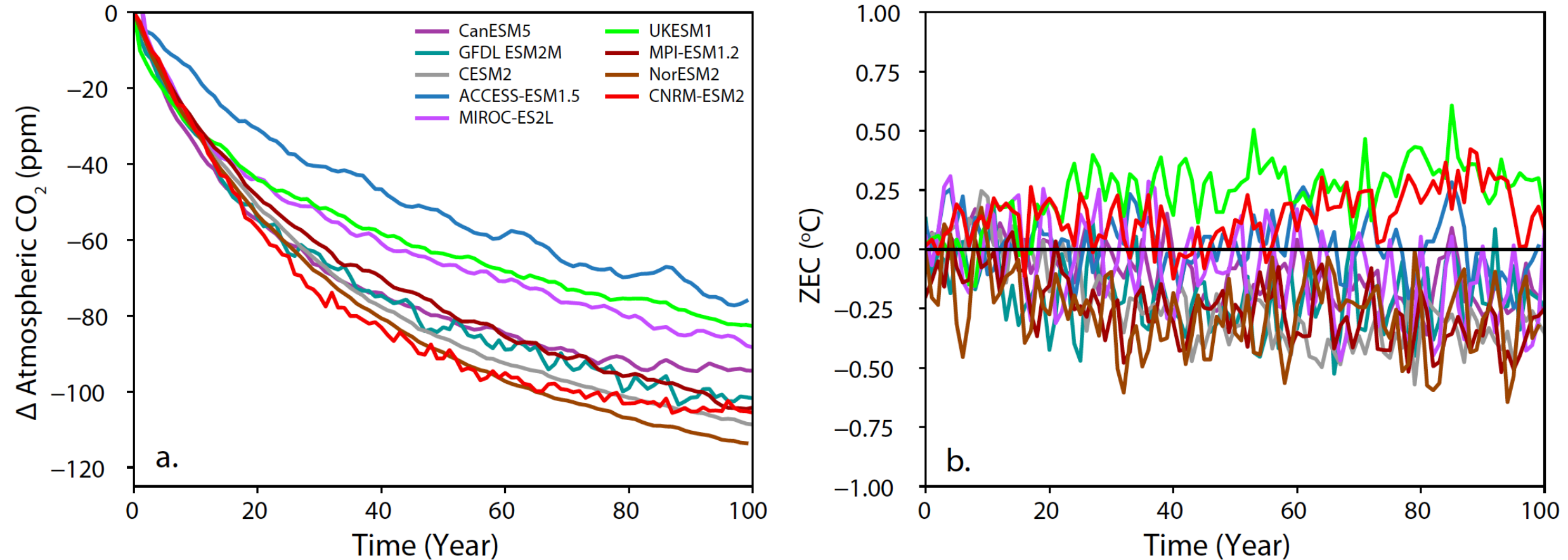
Results: ESMs

Figure 2: (a) Atmospheric CO_2 concentration anomaly and (b) Zero Emissions Commitment following cessation of emissions under the experiment where 1000 PgC was emitted following the 1% experiment (A1). Results for full complexity Earth System Models (ESMs) shown.
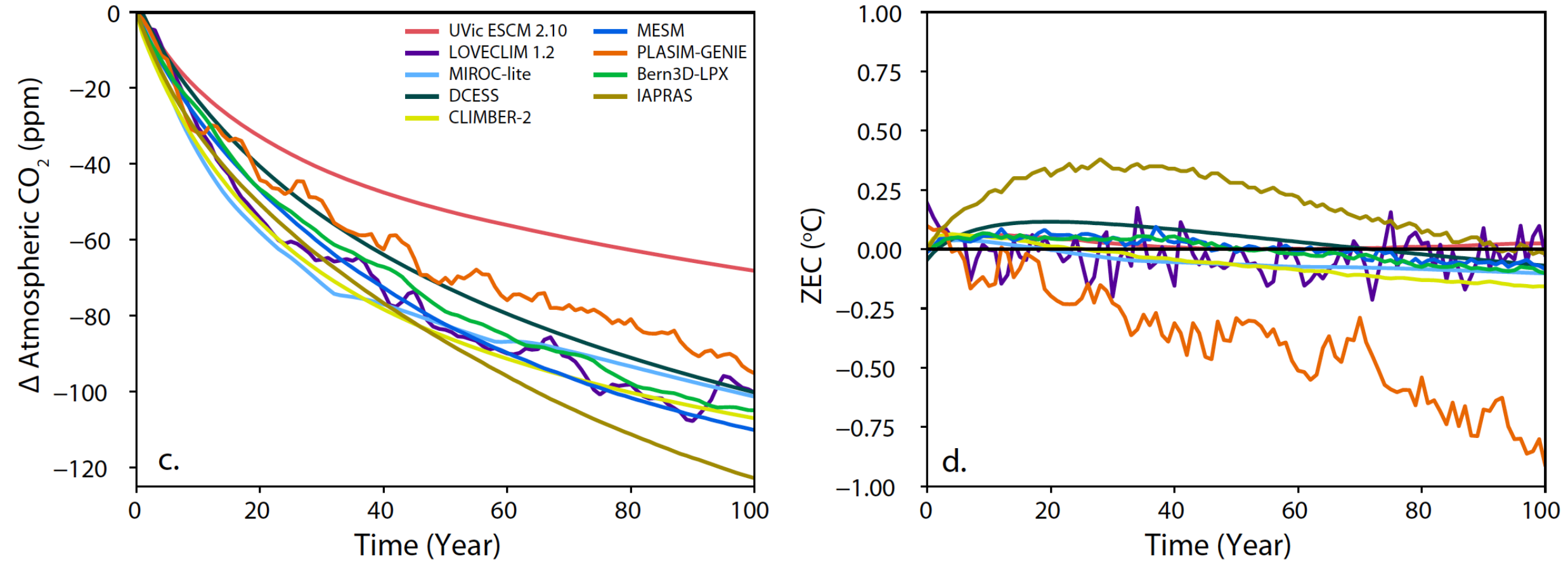
Results: EMICs

Figure 3: (c) Atmospheric CO_2 concentration anomaly and (d) Zero Emissions Commitment following cessation of emissions under the experiment where 1000 PgC was emitted following the 1% experiment (A1). Results for Earth System Models of Intermediate Complexity (EMICs) shown.
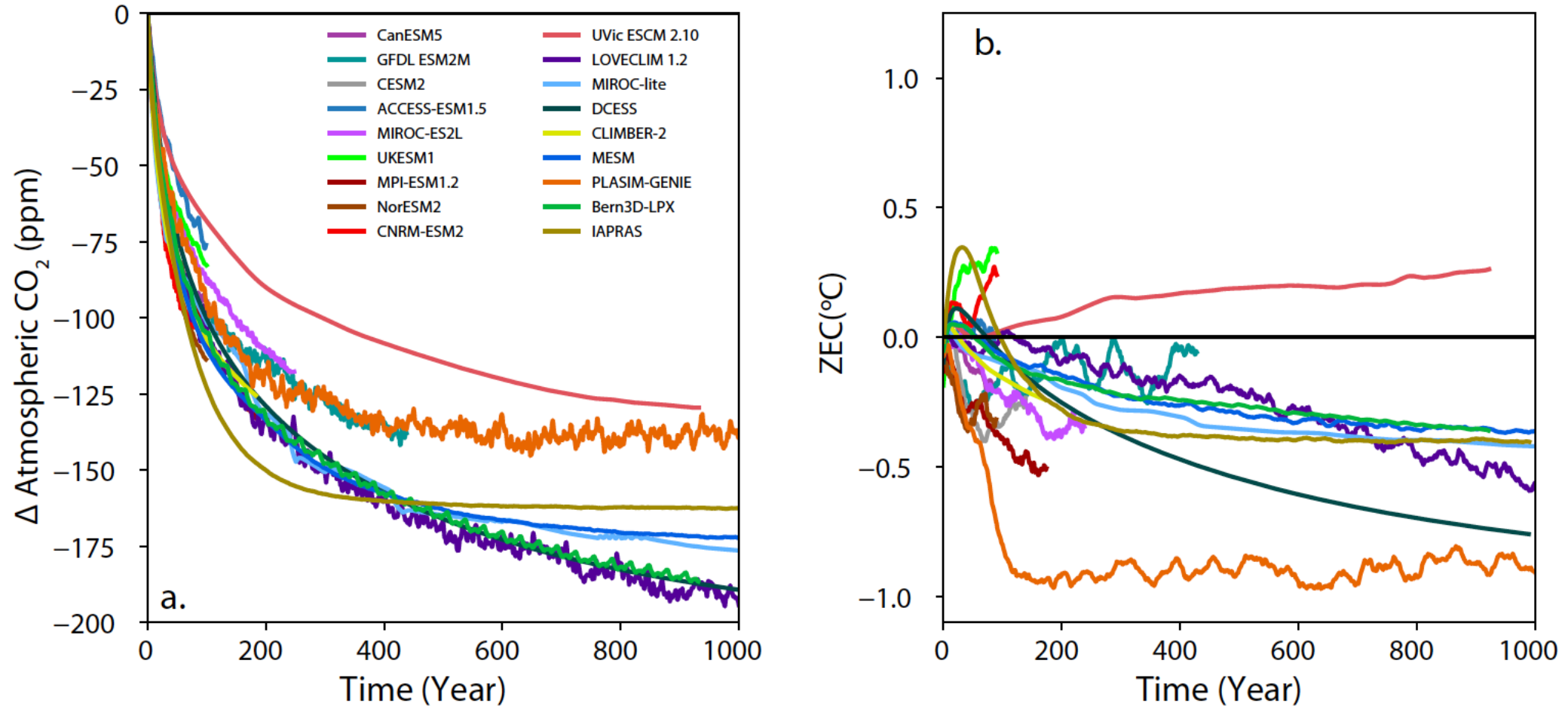
Results: Long Term

Figure 4: (a) Change in atmospheric CO_2 concentration, and (b) change in temperature following cessation of emissions for the A1 experiment (1000 PgC following 1%) for 1000 years following cessation of emissions.
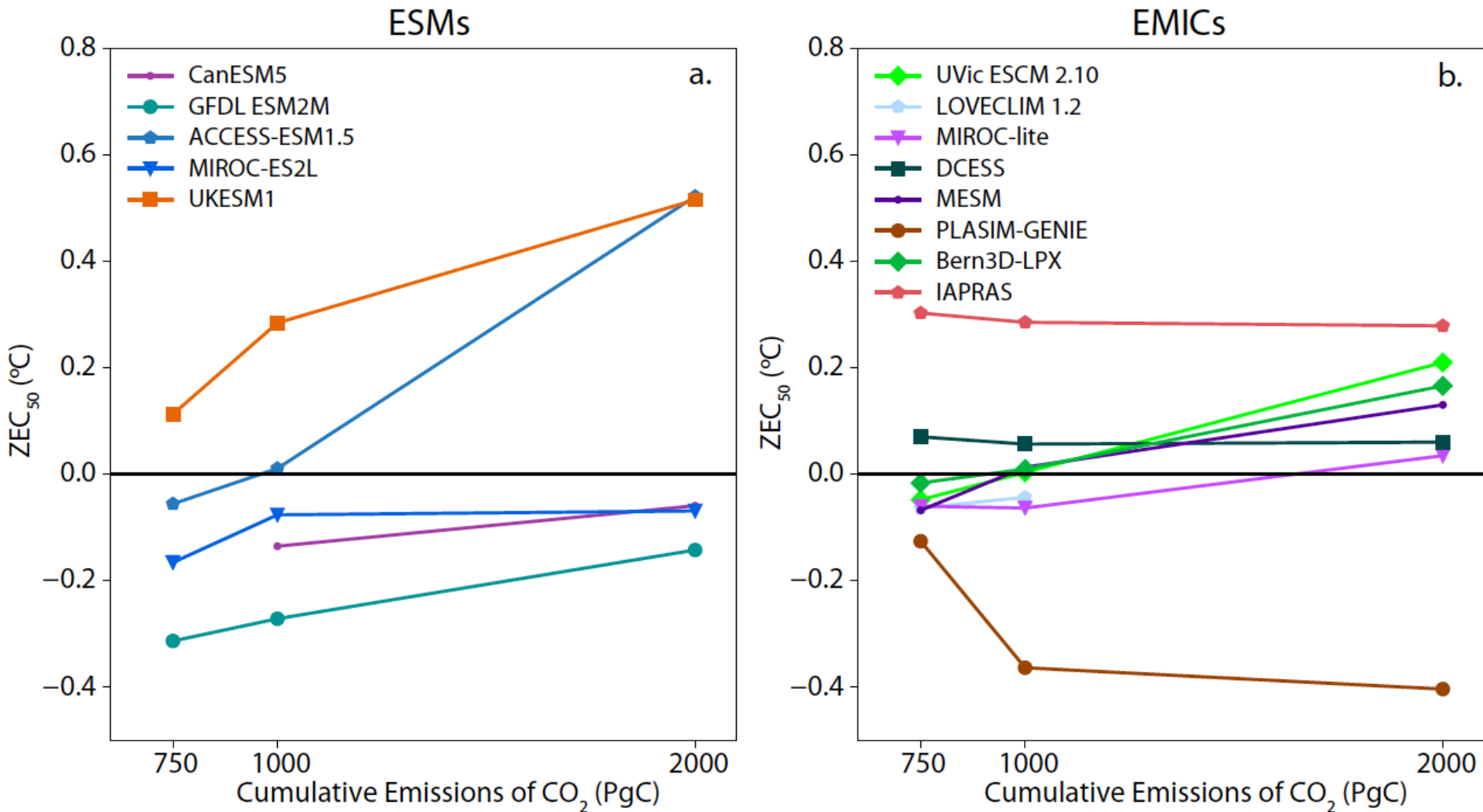
Results: Effect of Total Emissions

Figure 5: Values of ZEC_{50}* for the 750, 1000 and 2000 PgC experiments branching from the 1% experiment (type-A). Panel (a) shows results for full ESMs and panel (b) for EMICs

* ZEC_{50} is ZEC averaged from year 40 to 59 after emissions cease

Analysis Framework

$$\lambda T_{ZEC} = -F_{ocean} - F_{land} - \epsilon(N - N_{ze})$$

$$F_{ocean} = R \int_{t=ze}^{\infty} \frac{f_O}{C_A} dt \qquad F_{land} = R \int_{t=ze}^{\infty} \frac{f_L}{C_A} dt$$

Where λ (Wm^{-2}K^{-1}) is the climate feedback parameter, T_{ZEC} (K) is the zero emissions commitment, ε (-)is the efficacy of ocean heat uptake, N (Wm^{-2})is ocean heat uptake, R (Wm^{-2}) is the radiative forcing from an e-fold increase in atmospheric CO_2 burden, t is time (a), f_O is ocean carbon uptake (PgC a^{-1}), C_A is atmospheric CO_2 content (PgC), and f_L is land carbon uptake (PgC a^{-1}).
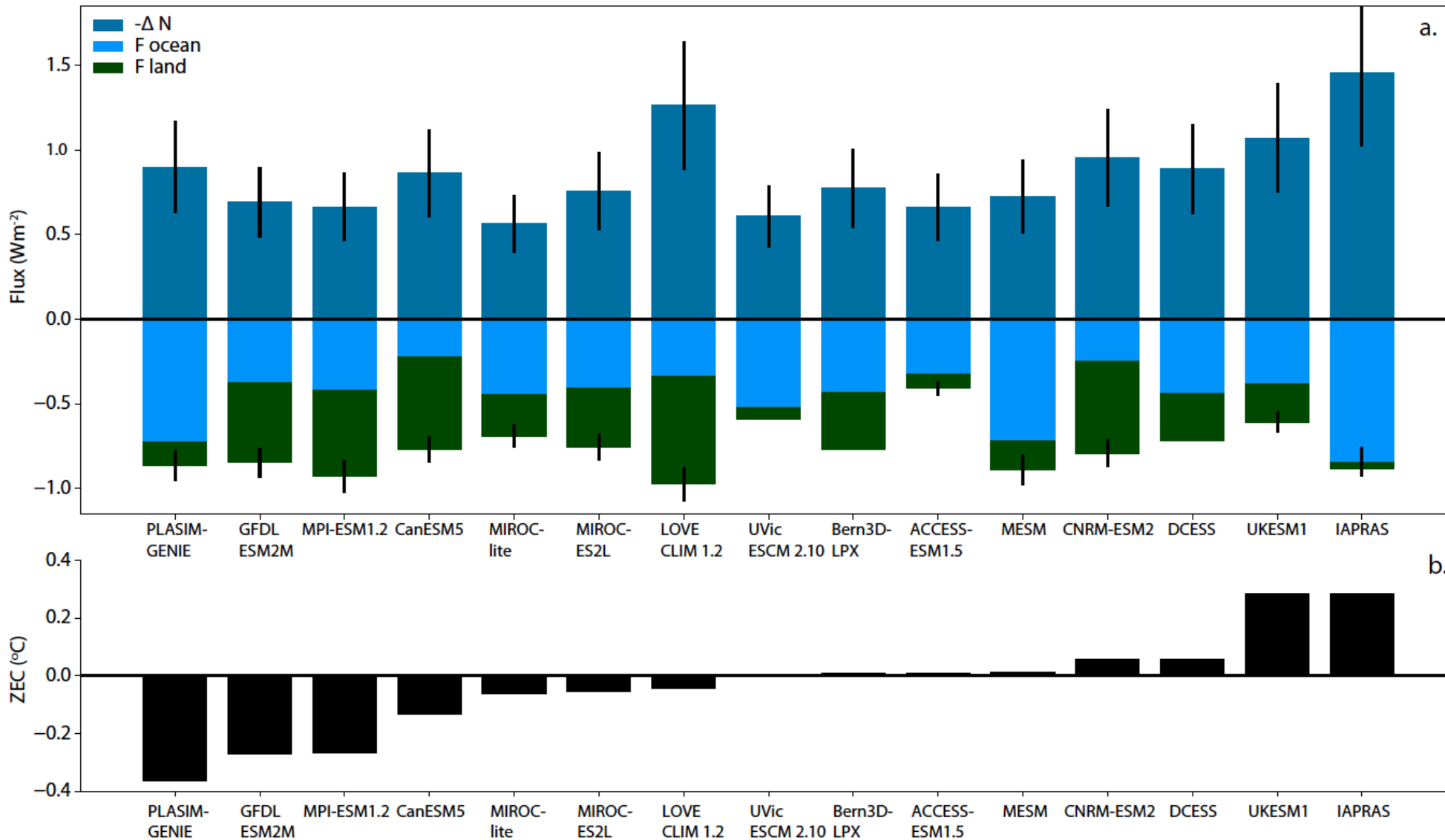
Analysis Framework

Figure 6. (a) Energy fluxes following cessation of CO_2 emissions for the 1000 PgC 1% (A1) experiment. (b) ZEC_{50} values for each model. Models are arranged in ascending order of ZEC_{50}.
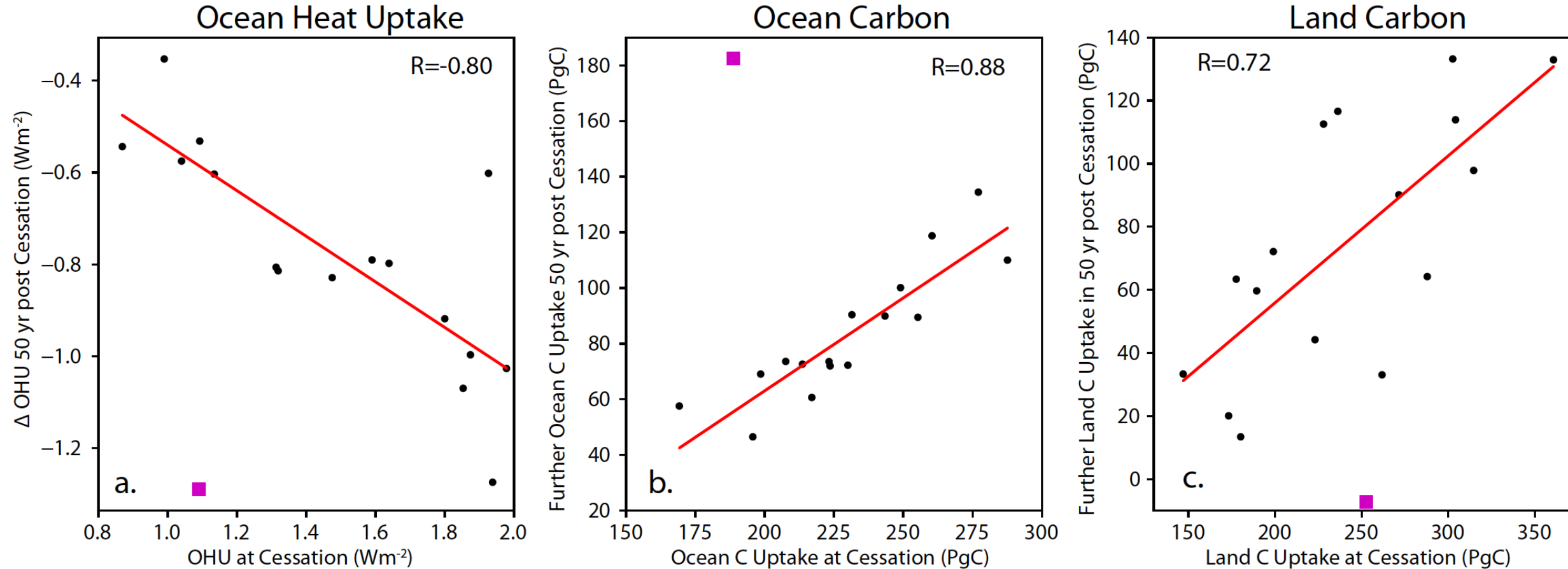
Analysis

Figure 7: Relationship between variables before emissions cease and 50 years after emissions cease. Each marker represents value from a single model. Line of best fit excludes the outlier model IAPRAS which is marked with a magenta square.

Conclusions

Inter-model range of ZEC 50 years after emissions cease for 1000 PgC experiment is -0.36 to 0.28 ^{o}C, with an ensemble mean of -0.07^{o}C, median of 0.05^{o}C, and standard deviation of 0.19^{o}C.

All models agree that following cessation of CO_2 emissions atmospheric CO_2 concentration will decline.

Analysis shows that both ocean carbon uptake and land carbon uptake are crucial for reducing atmospheric CO_2 concentrations.

Overall, the most likely value of ZEC on decadal time-scales is assessed to be close to zero. However substantial continued warming for decades or centuries following cessation of emission cannot be ruled out.

Paper

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