Can we constrain ZEC using observable metrics?

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After 'Zero CO_2': Tracing uncertainties in the Zero Emissions Commitment (ZEC) signal

1) Motivation

- Zero Emissions Commitment (ZEC) is the temperature response after emissions cease. In practice, ZEC is not observable.
- Models ZEC_{50} range: $\pm$ 0.3 °C
  ⇒ implications for the remaining carbon budget
- ZEC determined by balance between carbon uptake and ocean heat uptake [1] (i.e. observable metrics)

→ Can we use these metrics to constrain ZEC?

Can we describe ZEC as a function of observable metrics?

$$ZEC \sim f\left[\begin{pmatrix} DIC_{1950s} \\ DIC_{2000s} \\ \Delta DIC_{2000s\text{-}1950s} \end{pmatrix}, \begin{pmatrix} OHC_{1950s} \\ OHC_{2000s} \\ \Delta OHC_{2000s\text{-}1950s} \end{pmatrix}, \begin{pmatrix} cLand_{1950s} \\ cLand_{2000s} \\ cLand_{2000s\text{-}1950s} \end{pmatrix}\right]$$

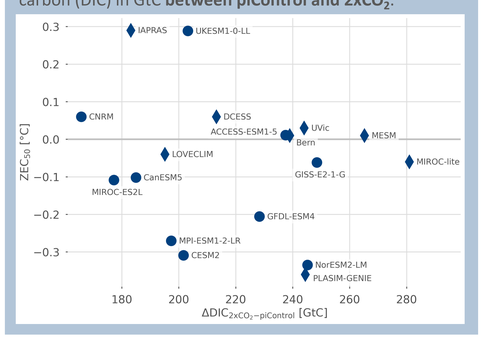
Dissolved inorganic carbon | **Upper ocean heat content** | **Land carbon content**

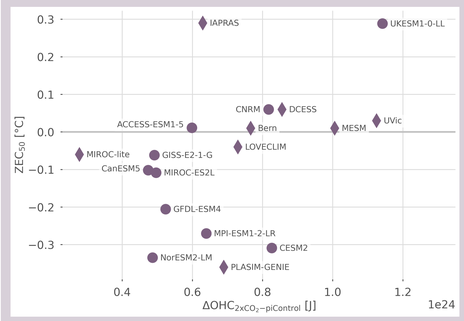
2a) Relationship with ocean heat and carbon in the idealised warming scenario

- ZECMIP simulations from 19 models [1,2]: 10 full (●), 9 intermediate complexity (◆)
- 30-year averages from piControl run and idealised 1pctCO2 experiment at time of doubled CO2 concentrations ($2xCO_2$); ZEC_{50} from abrupt cessation simulation

The ZEC signal shows no clear relation with **changes in DIC.**

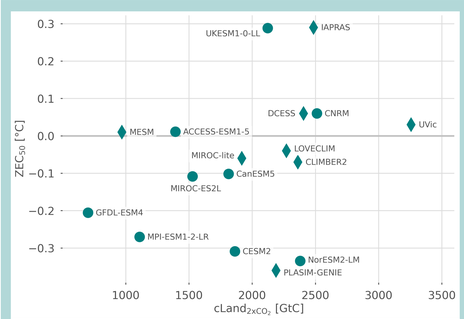
Fig. 1: As in Fig. 3 but for the change in dissolved inorganic carbon (DIC) in GtC **between piControl and $2xCO_2$.**





The ZEC response after 50 years shows some relation with **changes in OHC** during the idealised warming period:
high ΔOHC ~ high |ZEC|
⇒ further investigation needed.

Fig. 2: As in Fig. 3 but for the change in the global upper ocean (0-2000m) heat content (OHC) in J **between piControl simulation and $2xCO_2$.**



The ZEC signal shows also no clear relation with the global **land carbon content** at doubled CO_2 concentrations**.**

Fig. 3: Total global land carbon stock in GtC **at the point of doubled atmospheric CO_2 concentrations ($2xCO_2$)** against ZEC_{50} in °C. ZEC_{50} is the change in global mean temperature in the 50 years after emissions cease as simulated by the esm1pct-brch-1000PgC experiments [1,2].

2b) Correlation matrix of observable metrics

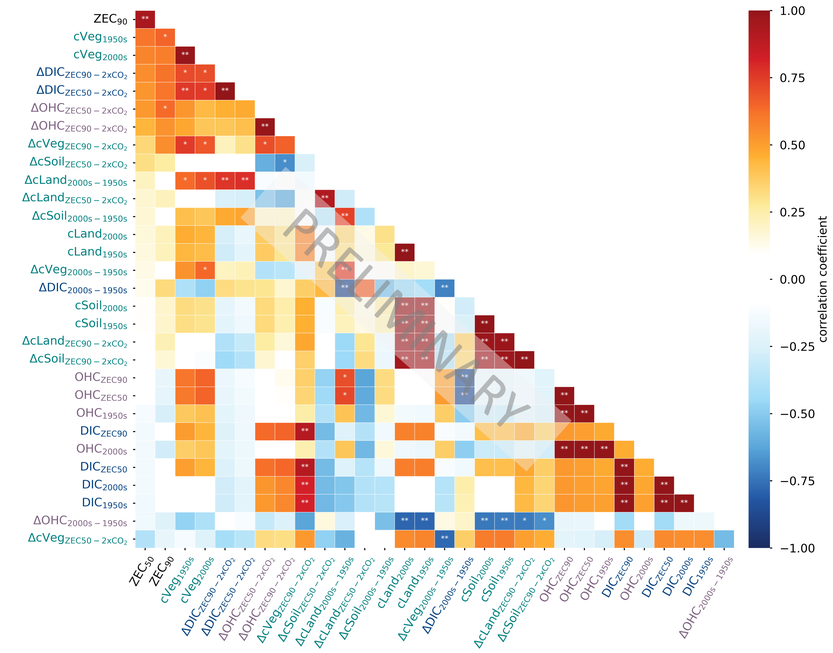


Fig. 4: Correlation matrix based on 30-year averages of 9 ESMs from historical simulations and esm-1pct-brch-1000PgC experiments. The averaging periods are centred as indicated by the variable names' subscripts: 1950s/2000s - historical year 1950/2000; 2xCO2 - doubled CO_2 concentrations in 1pctCO2 run; ZEC50/ZEC90 - 20-year averages around year 50/90 after cessation. Correlations are significant at *: p < 0.10, **: p < 0.05.

3) Outlook

- Use of perturbed parameter ensemble by UVic ESCM for further correlation analyses.
  → Investigate balancing effects between models' land and ocean carbon.
- Examine the feasibility of fitting a multi-linear regression model.
- Explore the possibility of applying observational products to constrain ZEC estimates.

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References:
1) MacDougall AH, Frölicher TL, Jones CD, Rogelj J, Matthews HD, Zickfeld K, et al. Is there warming in the pipeline? A multi-model analysis of the Zero Emissions Commitment from CO2. Biogeosciences. 2020 Jun 15;17(11):2987–3016.
2) Jones CD, Frölicher TL, Koven C, MacDougall AH, Matthews HD, Zickfeld K, et al. The Zero Emissions Commitment Model Intercomparison Project (ZECMIP) contribution to C4MIP: quantifying committed climate changes following zero carbon emissions. Geoscientific Model Development. 2019 Oct 15;12(10):4375–85.

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