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Supplement of

The mechanisms of North Atlantic CO_2 uptake in a large Earth System Model ensemble

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Fig. S 1: Illustrative values for the strength (Sv) of the different pathways through which water and therefore DIC can enter the surface subploar North Atlantic box under each set of box model parameters. Horizontal advection refers to the top right horizontal red arrow, and vertical mixing the right vertical blue arrow in figure 3 (main manuscript). In the box model the horizontal advection examined here is calculated by multiplying the MOC strength by the sum of parameters 'a' and 'b', and the vertical mixing value is described by the parameter 'mix_{north}' (tables 1 and 2, main manuscript). To illustrate typical flux values in this table, calculations have been made assuming a constant MOC strength of 18Sv.

Parameter set rank (as described in main manuscript table 2)	Horizontal advection (Sv)	Vertical mixing (Sv)
1	5.3	1.0
2	1.7	19.2
3	13.3	13.1
4	8.0	6.8
5	1.6	8.3
6	16.1	10.9

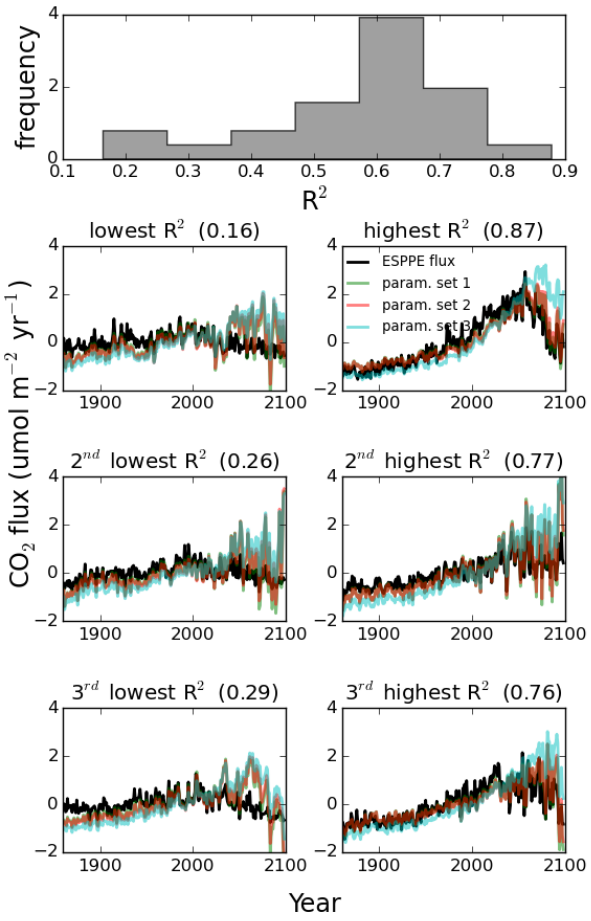

Fig. S 1: **Top:** Histogram showing the distribution of R^2 values describing the relationship between box-model and ESM simulations for each of the 27 ensemble members (using parameter set 1). **Lower plots:** Subpolar North Atlantic air-sea flux simulated within the ESPPE (grey), and emulation of that flux within the box model using the three parameter sets resulting in the highest mean R^2 value, i.e. the 1^{st}, 2^{nd} and 3^{rd} ranked parameter sets in table 2 in the main manuscript) displayed in green, red and blue respectively. The three ensemble members displaying the highest R^2 between ESSPE and box model with parameter set 1, and the three ensemble members displaying the lowest R^2 between ESSPE and box model with parameter set 1 are displayed on the right and left with the best (worst) fit at the top. We highlight the difference in goodness of fit between best and worst situations to demonstrate that it is small compared to common behaviour, i.e. the behaviour that we are trying to understand. Results presented as anomalies from the mean value.

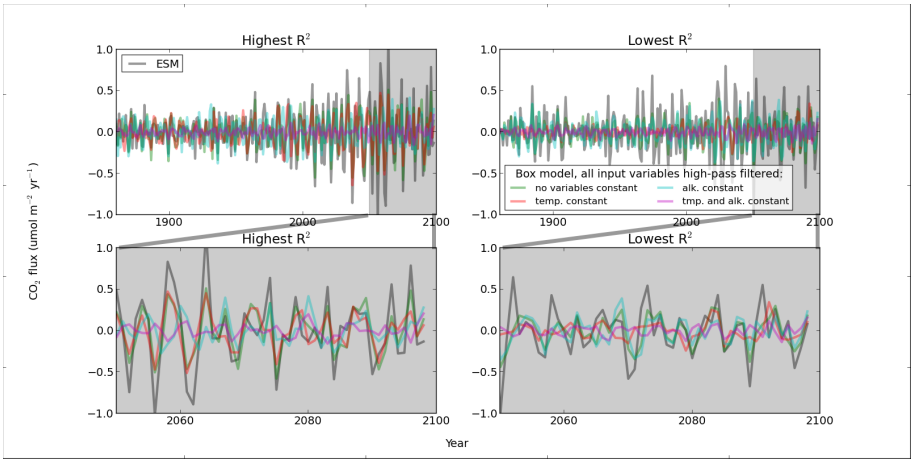

Fig. S 2: Illustration of the fit (best and worst case as assessed by R^2) between high-pass filtered ESPPE North Atlantic subpolar gyre air-sea CO_2 flux and the box model results when driven with high-pass filtered input time-series. Similarity between the dark blue (ESPPE subpolar North Atlantic air-sea CO_2 flux) and green lines illustrates the box model's ability to capture high frequency variability in the ESM ensemble. Red, light blue and purple lines show how the box-model's fit to the ESPPE's high-frequency subpolar North Atlantic air-sea CO_2 flux variability is dependant on temperature and alkalinity. Factors other than temperature and alkalinity do not play an important role in variability on this timescale (see main manuscript) so have been excluded from this figure for clarity. All results are presented as anomalies from the mean.

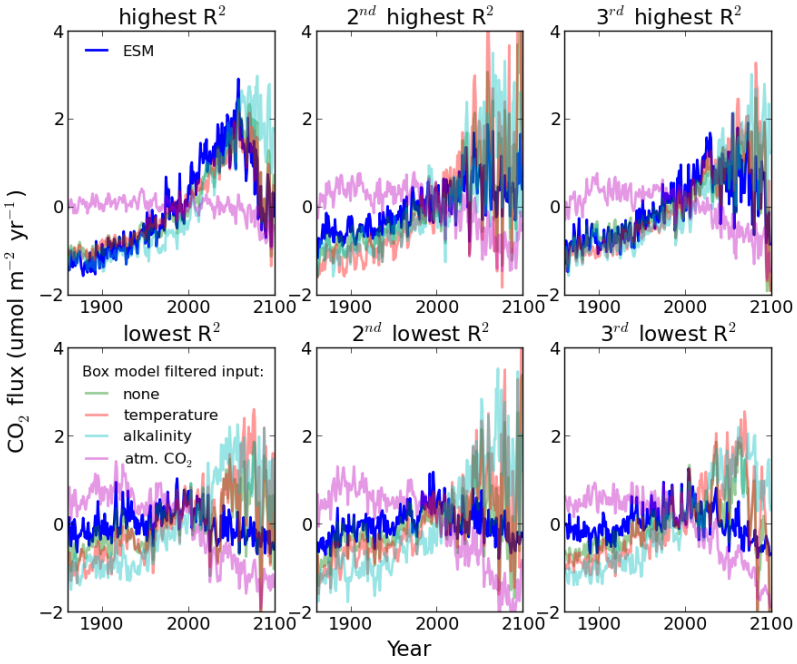

Fig. S 3: Illustration of the fit (three best and worst case ensemble members as assessed by R^2) between low-pass filtered ESPPE North Atlantic subpolar Gyre air-sea CO_2 flux and the box model results when driven with individual input time-series which have been high-pass filtered. Similarity between the dark blue and green lines highlights the box model's ability to replicate the ESM ensemble's behaviour. Further colours illustrate the dependance of that fit on the time-evolution of the various input variables. All results are presented as anomalies from the mean.

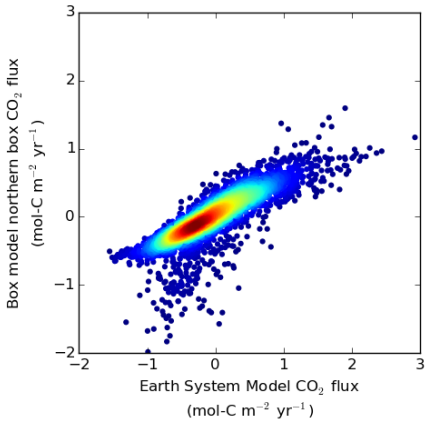

Fig. S 4: Results of box model validation exercise. Half of the ESPPE members were randomly selected, and the box model tuned (as described in the main text) to emulate those members. The box model was then run with the inputs from the remaining half of the ESPPE (i.e. those ensemble members excluded from the tuning ensemble) to assess the predictive skill of the box model. The results presented are annually averaged North Atlantic Subpolar air-sea CO_2 fluxes from the ESPPE members excluded form the tuning exercise, plotted against the predictions from the box model.

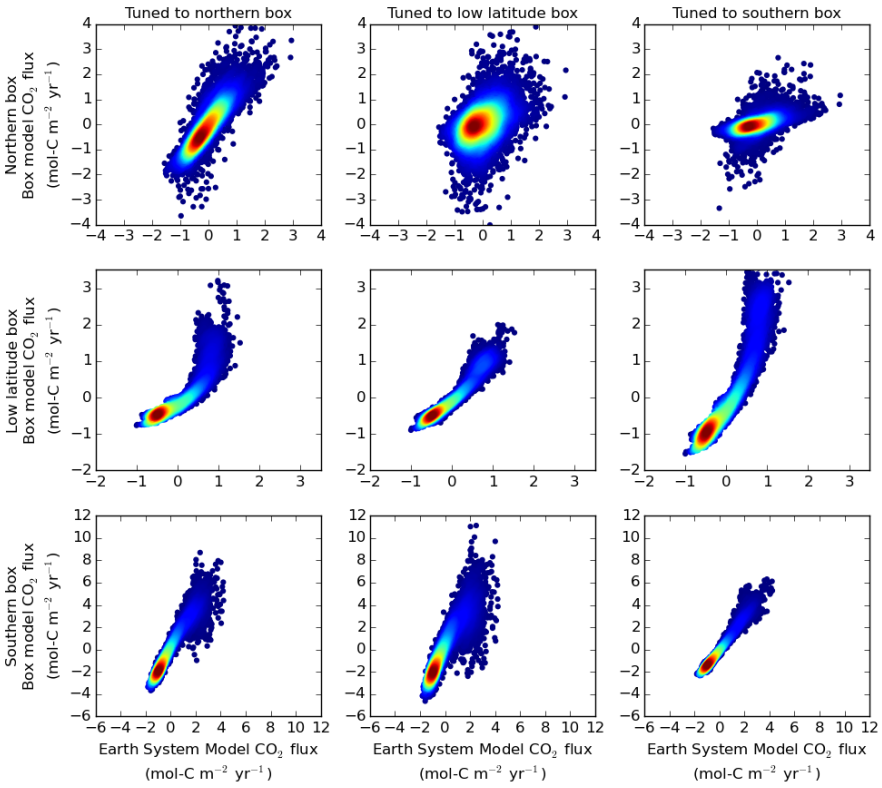

Fig. S 5: Earth System Model (ESPPE) annually-averaged values averaged across the northern, low-latitude and southern boxes (top to bottom), plotted against annually-averaged values from the box model from the same regions. Columns present results from (left) box model tuned to replicate the northern box values form the ESPPE, (middle) box model tuned to replicate ESPPE values from the low-latitude box, and (right) box model tuned to replicate ESPPE values from the southern box. Colours from blue to red represent an increasing density of points.

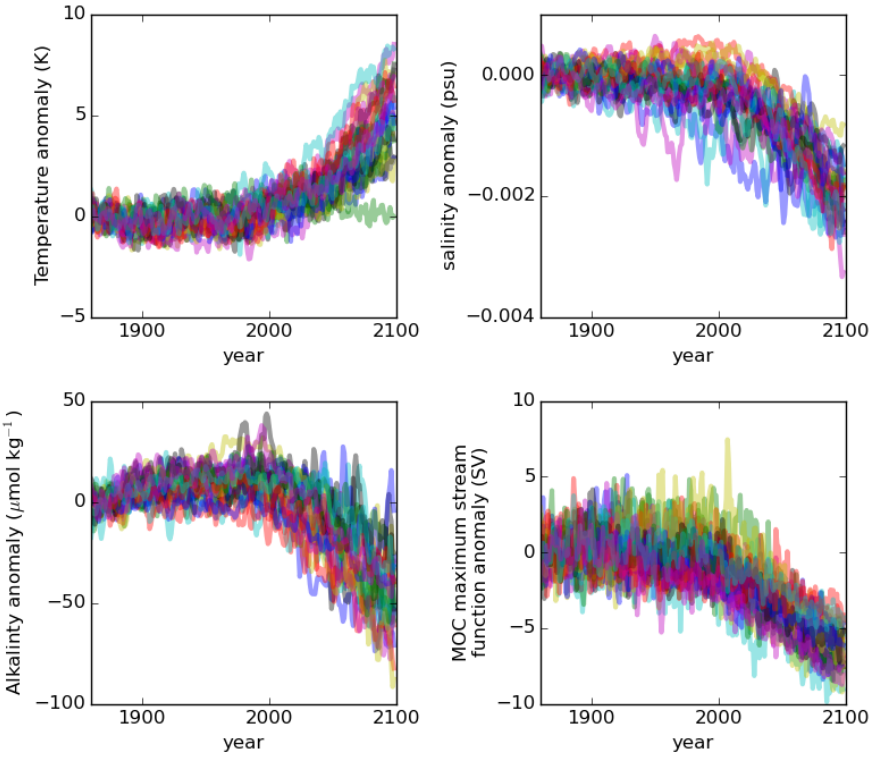

Fig. S 6: Subpolar North Atlantic surface ocean temperature, salinity, alkalinity and maximum overturning stream function plotted from the ESPPE simulations as anomalies from their respective first 20 year mean values. Different coloured lines represent different ensemble members.