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Supplementary Materials for

Predicting the variable ocean carbon sink

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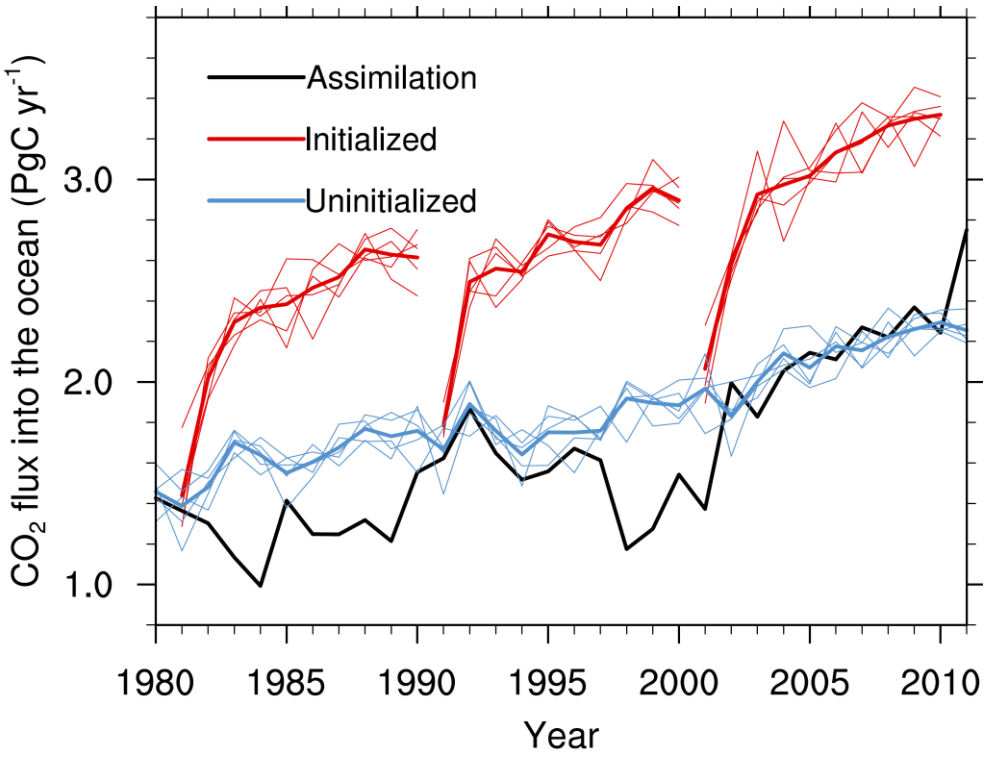

Fig. S1. Time series of the CO_2 flux into the ocean from MPI-ESM-HR simulations. Here we show the 5 ensemble member (thin lines) and the ensemble mean (thick lines) results for both the uninitialized simulation (blue curve) and the initialized simulation starting from year 1980, 1990, and 2000 (red curves), together with the assimilation (black curve).

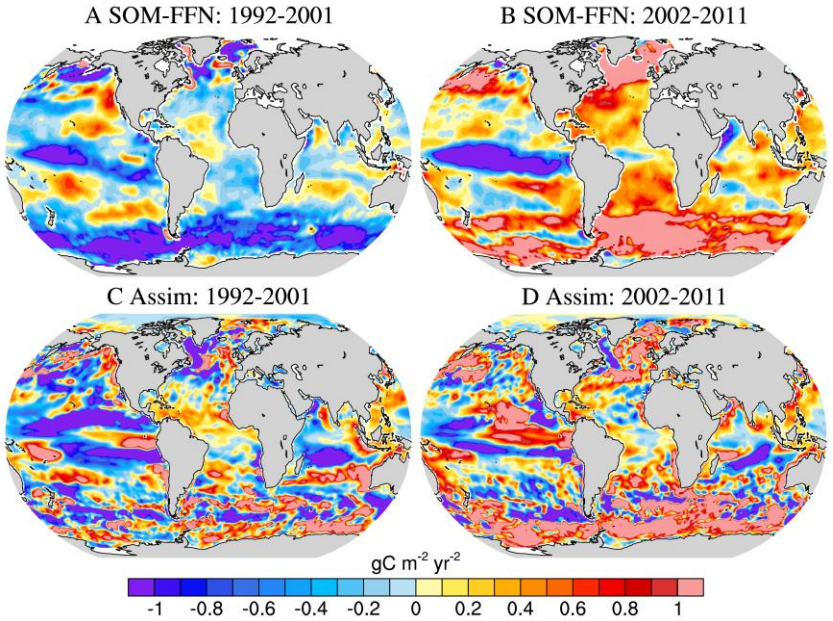

Fig. S2. Decadal trends of CO_2 flux into the ocean. The shown trends are from 1992-2001 (left panels) and 2002-2011 (right panels) based on the SOM-FFN data-based estimates (upper panels) and the MPI-ESM-HR assimilation (lower panels).

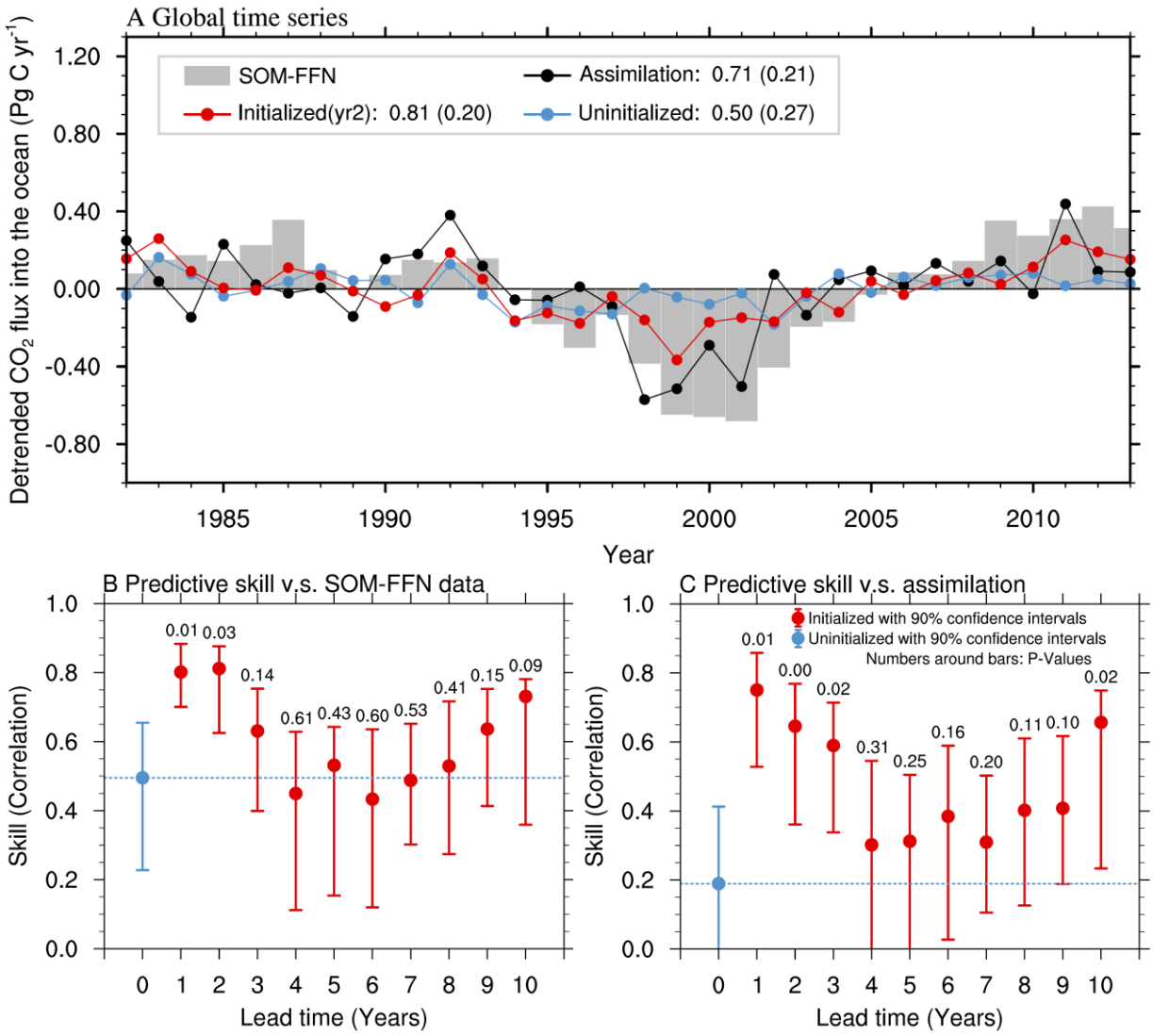

Fig. S3. The same as Fig. 1, but for detrended global CO_2 uptake by the ocean. The linear trend of the period from 1982-2013 is removed.

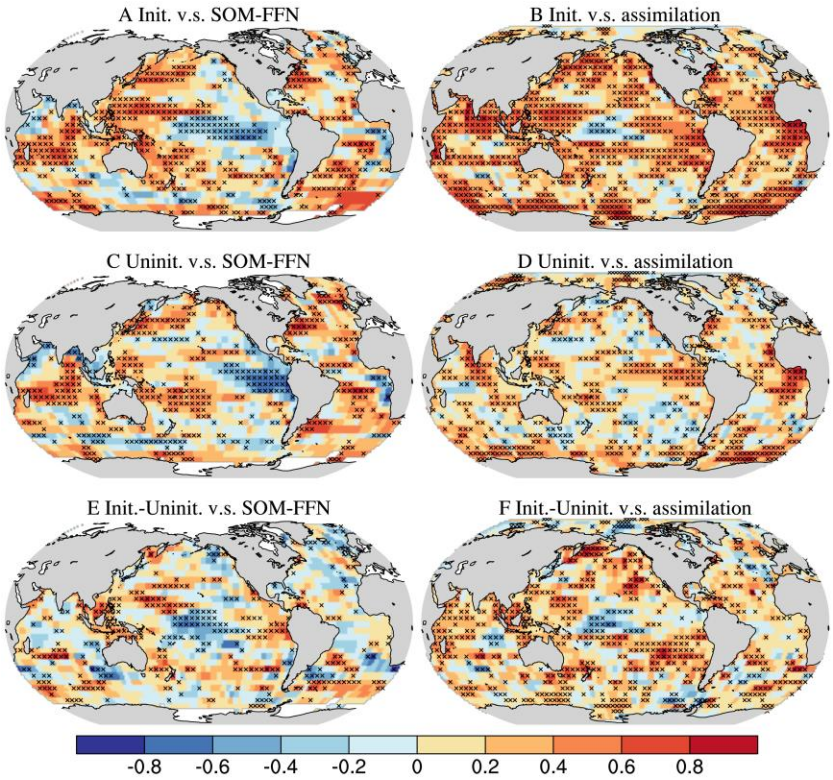

Fig. S4. Predictive skill of the air-sea CO_2 flux at a lead time of 2 years. We show skill against SOM-FFN data-based estimates (left panels) and against assimilation (right panels). 1st row: correlations with initialized simulations, 2nd row: correlations with uninitialized simulations, 3rd row: difference of correlations between initialized and uninitialized simulations. The values are computed over the years from 1982-2013 with the MurCSS tool for central evaluation of predictive skill (*28*). Crosses denote significant skill at 95% confidence level based on a bootstrap approach (*27*).

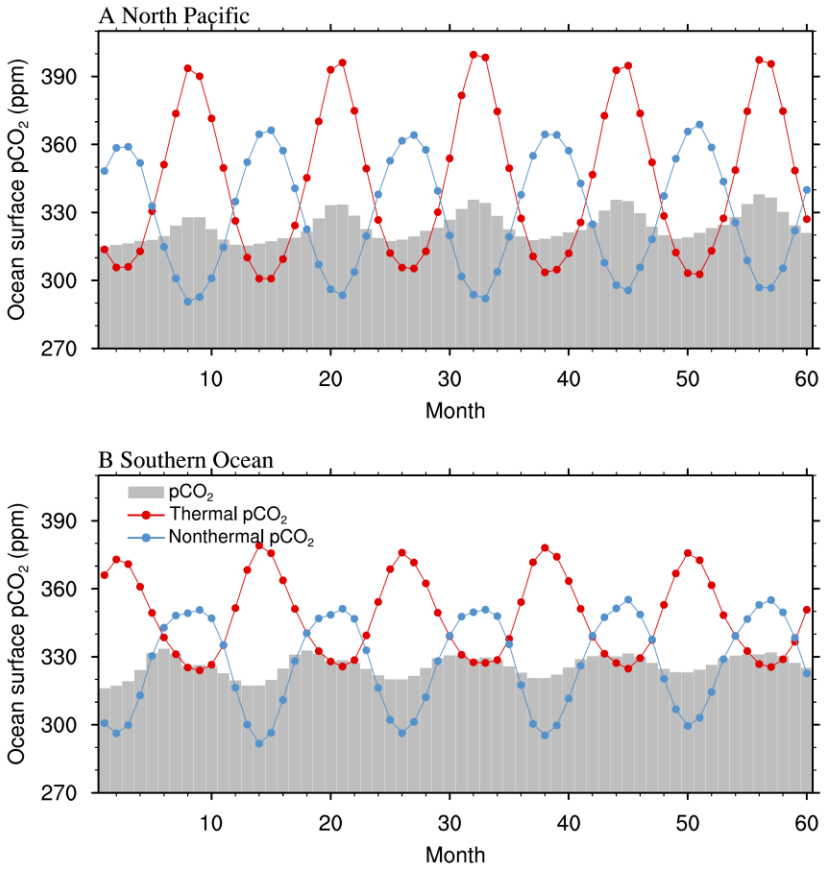

Fig. S5. Monthly ocean surface pCO_2 (gray bars) and its thermal (red) and nonthermal (blue) components. We show the first 5 years of the SOM-FFN data-based estimates from 1982-1986 in the North Pacific (**A**) and the Southern Ocean (**B**). Here the North Pacific is averaged in the ocean area from 110°E-210°E and from 10°N-60°N; and the Southern Ocean is averaged from the ocean area to the south of 35°S.

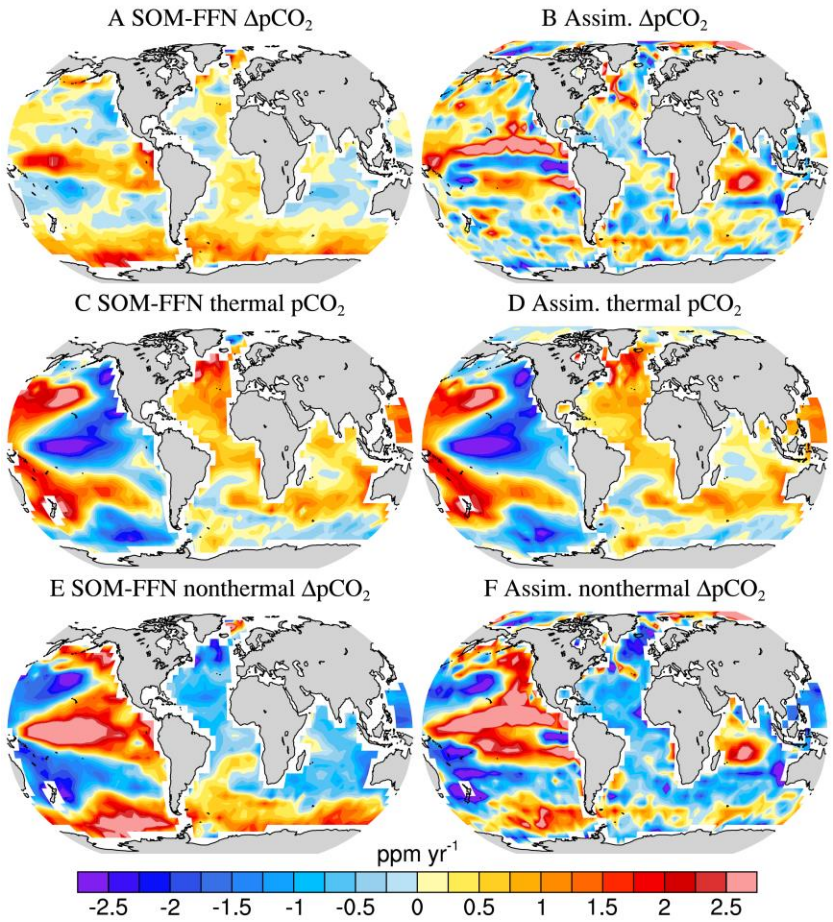

Fig. S6. Decadal trends of ΔpCO_2 ($pCO_2^{sea} - pCO_2^{atm}$) and its thermal and nonthermal components from 1992 to 2001. We show trends of the SOM-FFN data-based estimates (left panels) and the assimilation (right panels). The trends of ΔpCO_2 are shown in **A**-**B**. The thermal component trends are based on pCO_2^{sea} (**C**-**D**) and the non-thermal component trends are based on ΔpCO_2 (E-F) (*14*).

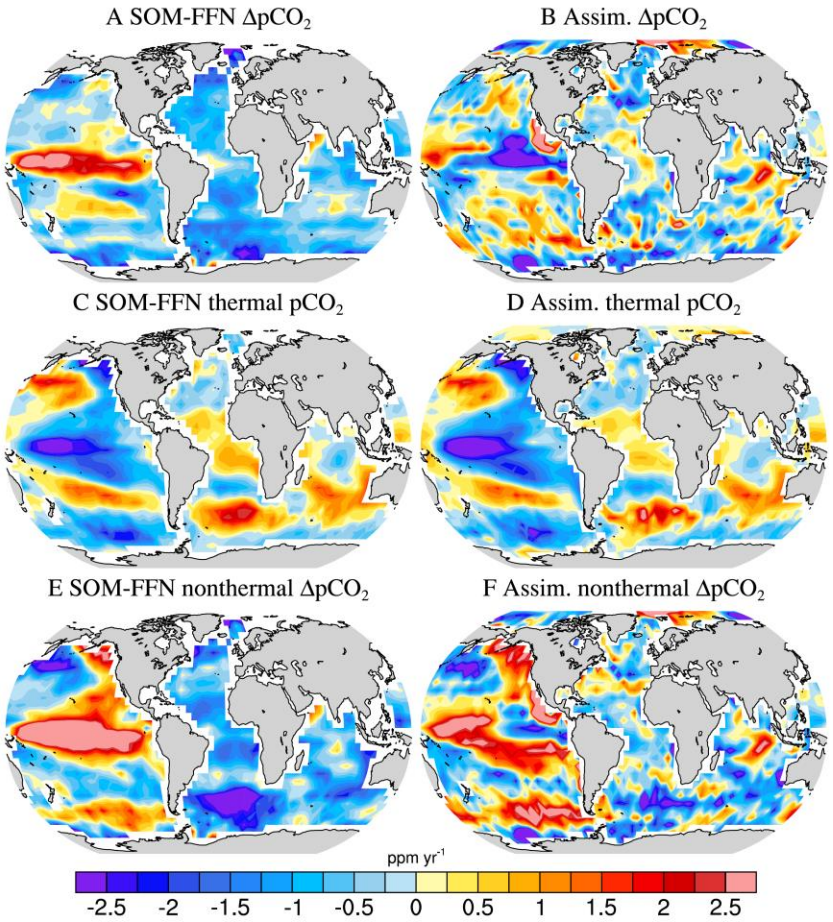

Fig. S7. The same as fig. S6, but for 2002–2011.

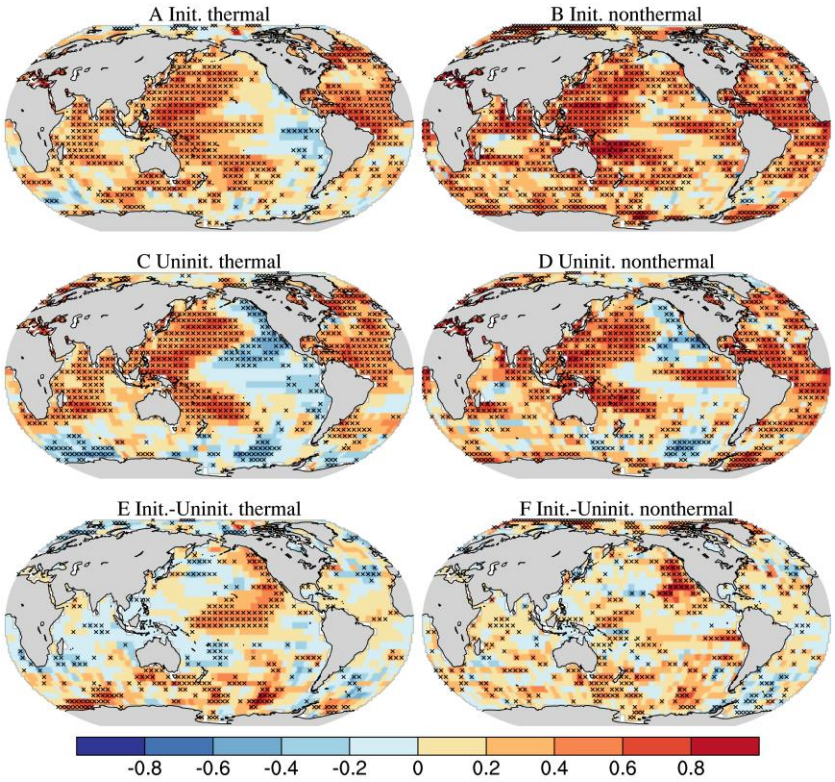

Fig. S8. Predictive skill of pCO_2 thermal and nonthermal components at a lead time of 2 years against assimilation. 1st row: correlations with initialized simulations, 2nd row: correlations with uninitialized simulations, 3rd row: difference of correlations between initialized and uninitialized simulations. The left column shows the predictive skill of the thermal component, and the right column shows the predictive skill of the non-thermal component. The values are computed over the years from 1982-2013 with the MurCSS tool for central evaluation of predictive skill (*28*). Crosses denote significant skill at 95% confidence level based on a bootstrap approach (*27*).

Table S1. Summary of the simulations used in this study based on the MPI-ESM-HR decadal prediction system.

Simulations	Nudging	Initial condition	Ensemble member	Length of simulation
Uninitialized	N/A	Preindustrial control simulation	5	1850-2005 historical 2006-2030 RCP4.5
Assimilation	Atm.: ERA Ocn.: ORAS4 anomalies Sea-ice: NSIDC	Uninitialized simulation	1	1958-2016
Initialized	N/A	Assimilation, started yearly on 1st Nov. and run for 10 years plus 2 months	5	1961-1970 1962-1971 …… 2013-2022