

*Geophysical Research letters*

Supporting Information for

**Observed Regional Fluxes to Constrain Modeled Estimates of the Ocean Carbon Sink**

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Text S1.

Globally and in the equatorial and subtropical regions, the ensemble of the observation-based products and the ensemble of models are in good agreement with regard to the phasing of interannual variability, both prior to and after selection (Figure S3). The high latitudes show limited agreement in either case. Selection does not significantly change interannual correlations (Supplementary Table 7).

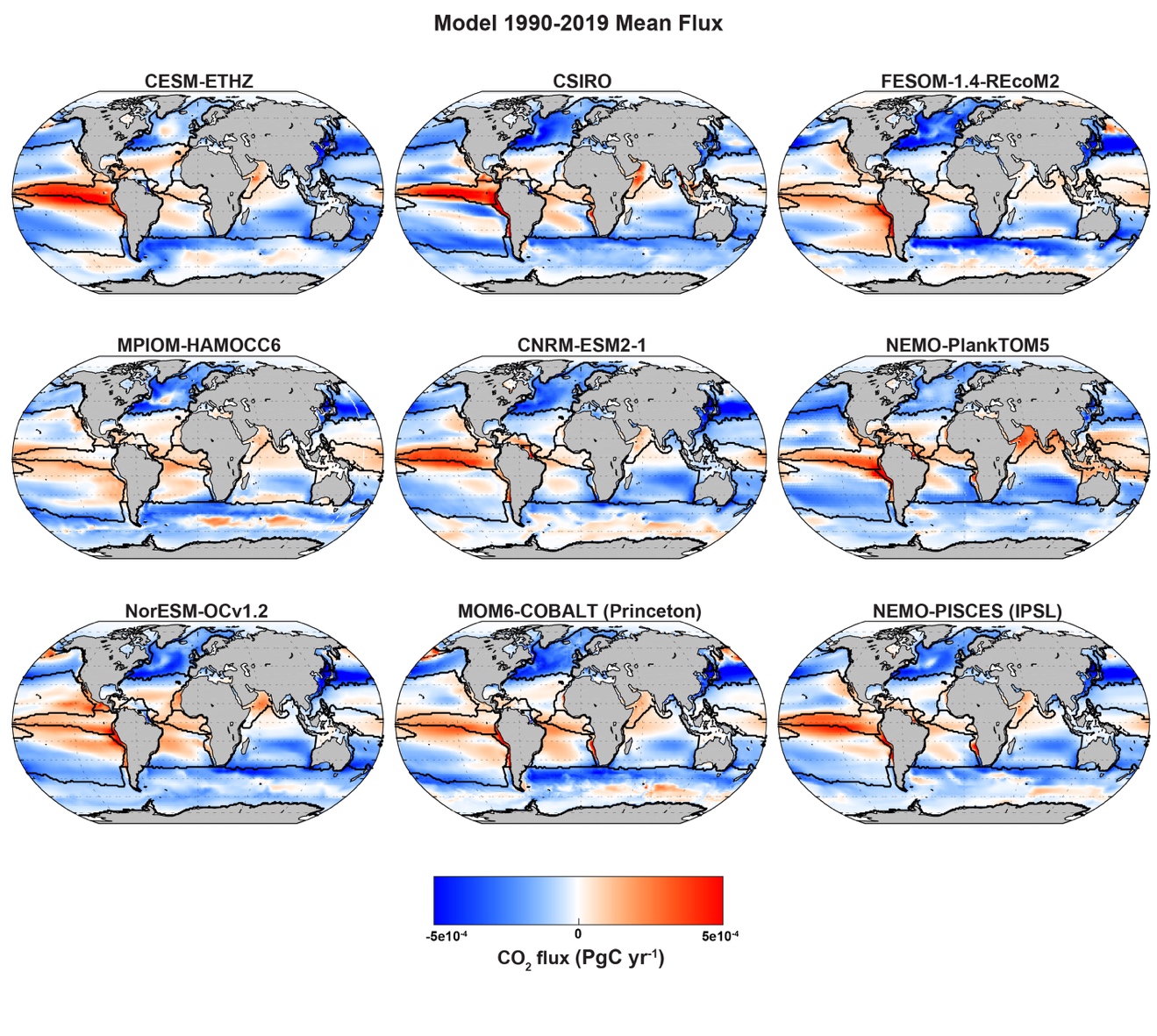


Figure S1. Maps showing mean 1990-2018 air-sea CO2 flux (PgC/yr) for each model. Black lines show boundaries for regional analysis (as in Figure 1).

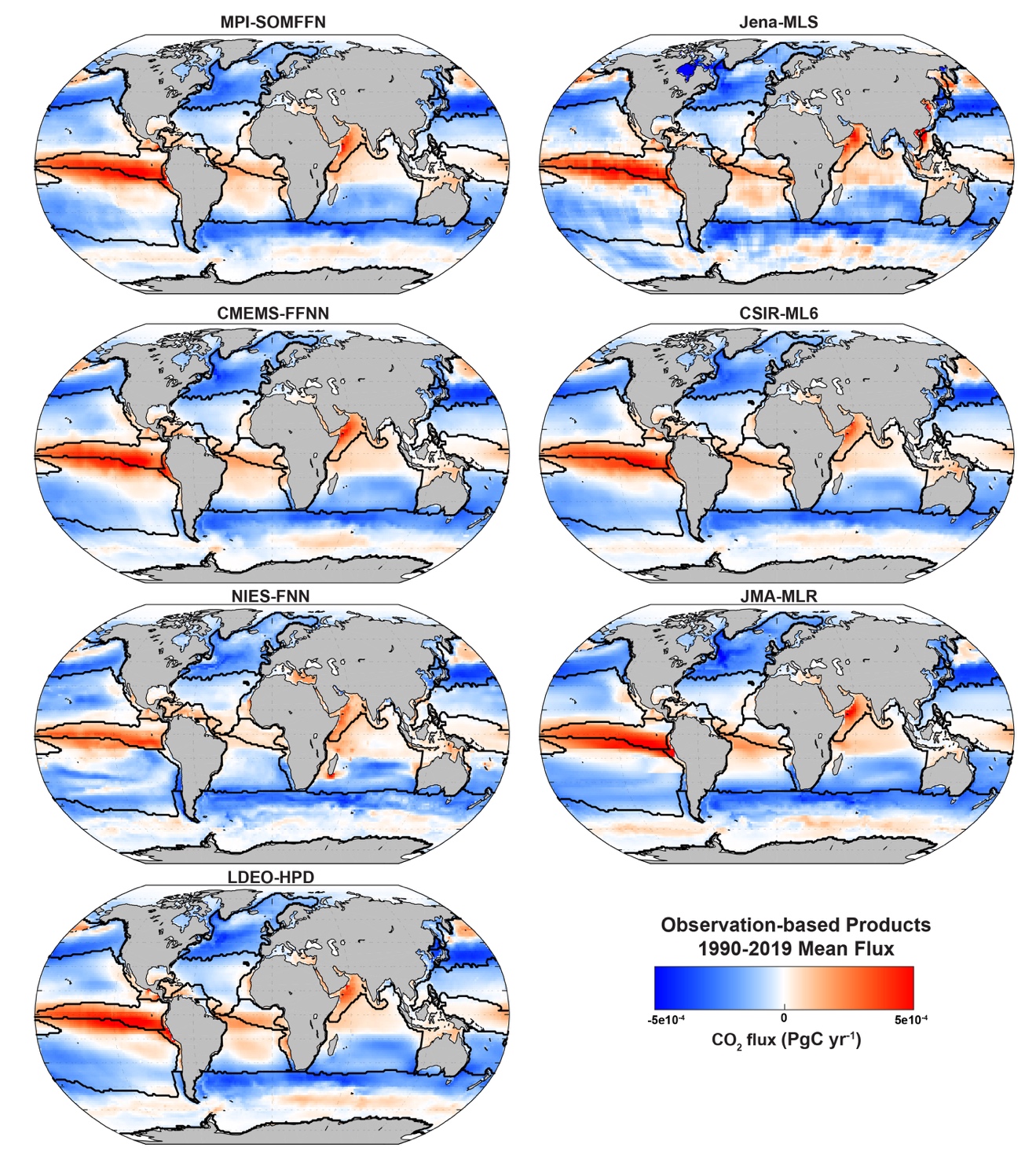


Figure S2. Maps showing mean 1990-2018 air-sea CO2 flux (PgC/yr) for each observation-based product. Black lines show boundaries for regional analysis (as in Figure 1).

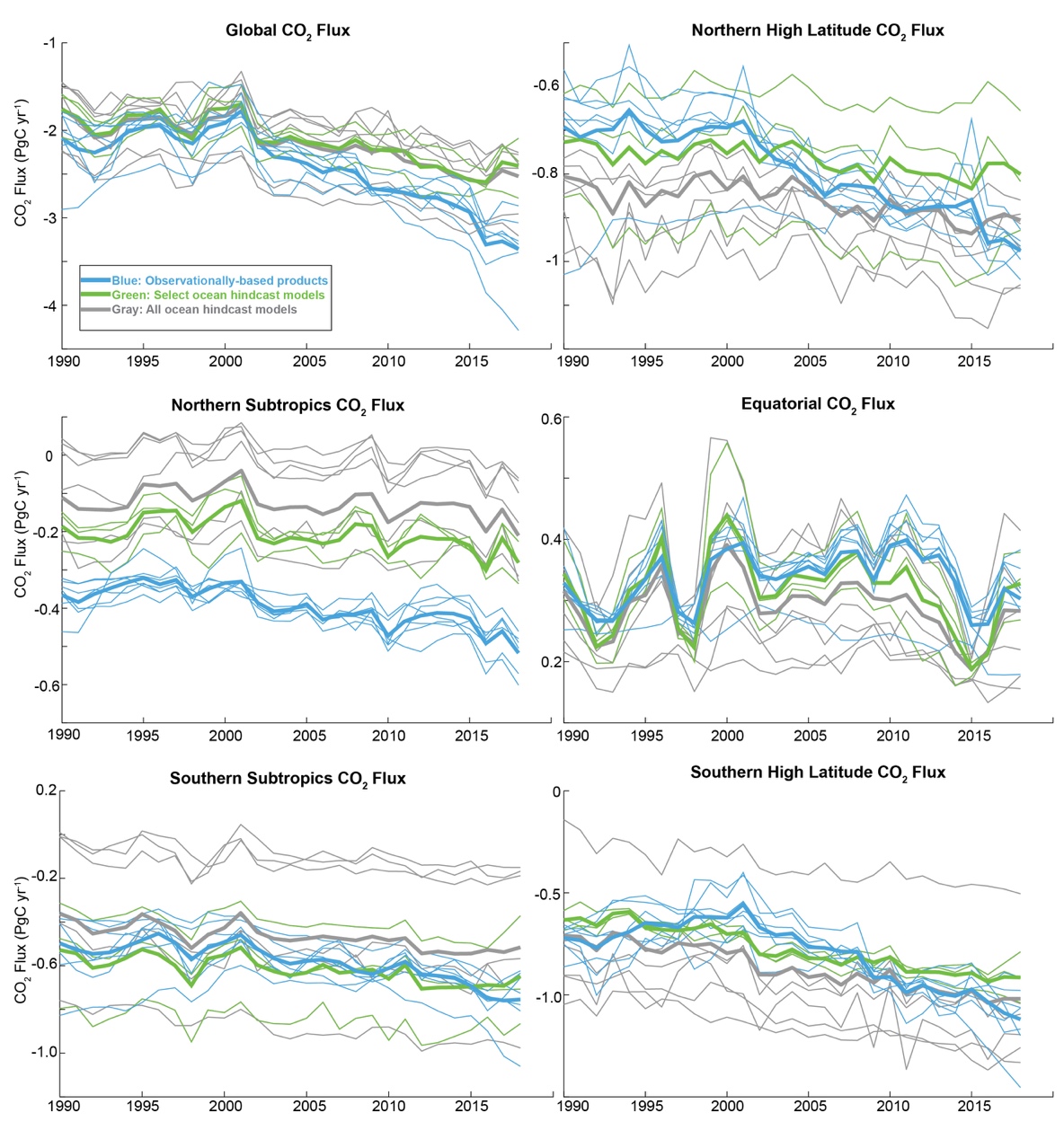


Figure S3. Time series for global and regionally-integrated air-sea CO2 fluxes (PgC/yr) from an ensemble of observation-based products (blue) and hindcast ocean models (gray and green), years 1990-2018. Thin lines are individual ensemble members while bold lines show mean for the products (blue), the full ensemble of models (gray) and the selected models (green).

Table S1. Observation-based pCO2 products and Hindcast Ocean Model names and references

Observation-based pCO2 products

|  |  |
| --- | --- |
| Name | *Reference* |
| CMEMS-FFNN | *Denvil-Sommer et al. 2019 Chau et al. 2020* |
| CSIR-ML6 | *Gregor et al. 2019* |
| Jena-MLS | *Rödenbeck et al. 2013* |
| JMA-MLR | *Iida et al. 2020* |
| LDEO-HPD | *Gloege et al. 2021* |
| MPI-SOMFFN | *Landschützer et al. 2014 Landschützer et al. 2020a* |
| NIES-FNN | *Zeng et al. 2014* |

Hindcast Ocean Models

|  |  |  |
| --- | --- | --- |
| Name | *Reference* | Selected |
| CESM-ETHZ | *Doney et al. 2009* | Yes |
| CNRM-ESM2-1 | *Berthet et al. 2019* | No |
| CSIRO | *Law et al. 2017* | No |
| FESOM-1.4-REcoM2 | *Hauck et al. 2020* | No |
| MOM6-COBALT (Princeton) | *Liao et al. 2020* | No |
| MPIOM-HAMOCC6 | *Paulsen et al. 2017* | No |
| NEMO-PISCES (IPSL) | *Aumont et al. 2015* | Yes |
| NEMO-PlankTOM5 | *Buitenhuis et al. 2010* | Yes |
| NorESM-OCv1.2 | *Schwinger et al. 2016* | No |

Table S2. River adjustment from Lacroix et al. (2020)

|  |  |  |
| --- | --- | --- |
| Region | Percent of river efflux | River flux adjustment (% \* 0.49PgC/yr) |
| Northern High Latitudes | 10.3% | 0.051 PgC yr-1 |
| Northern Subtropics | 27.2% | 0.133 PgC yr-1 |
| Equatorial | 3.7% | 0.018 PgC yr-1 |
| Southern Subtropics | 35% | 0.172 PgC yr-1 |
| Southern High Latitudes | 6.2% | 0.030 PgC yr-1 |

Table S3. River adjustment from Lacroix et al. (2020) for latitude bounds as defined by Aumont et al. (2001).

|  |  |  |
| --- | --- | --- |
| Region | Lacroix % of river efflux | Aumont % of river efflux |
| 90N-20N | 34% | 26% |
| 20N-20S | 45% | 25% |
| 20S-90S | 21% | 49% |

**Table S4** Global and regionally integrated air-sea CO2 flux in PgC/yr for 7 observation-based products, products with river carbon efflux adjustment, all nine models, and select three models. Uncertainty (±) represents 2σ spread. Middle column shows the 3σ bounds on the product ensemble; this is used for the model selection criteria.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Products | Products natural outgassing due to rivers | 3σ Product spread | Models | Select Models |
| Global | -1.94 ± 0.32 | -2.43 ± 0.62 | -3.36; -1.50 | -2.15 ± 0.64 | -2.11 ± 0.42 |
| N High Latitudes | -0.74 ± 0.13 | -0.79 ± 0.14 | -1.01; -0.58 | -0.86 ± 0.25 | -0.77 ± 0.34 |
| N Subtropics | -0.26 ± 0.04 | -0.40 ± 0.15 | -0.62; -0.17 | -0.13 ± 0.22 | -0.21 ± 0.09 |
| Equatorial | 0.35 ± 0.08 | 0.33 ± 0.08 | 0.21; 0.46 | 0.29 ± 0.14 | 0.32 ± 0.10 |
| S Subtropics | -0.41 ± 0.16 | -0.58 ± 0.25 | -0.95; -0.21 | -0.47 ± 0.60 | -0.62 ± 0.45 |
| S High Latitudes | -0.77 ± 0.10 | -0.80 ± 0.10 | -0.95; -0.65 | -0.87 ± 0.48 | -0.77 ± 0.07 |

**Table S5** Coefficient of Variability (CoV) for global and regionally integrated air-sea CO2 fluxes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Observation-based Products | Products with natural outgassing due to rivers | Hindcast Models | Select Models |
| Global | 8% | 13% | 15% | 10% |
| NH High Latitudes | 9% | 9% | 15% | 22% |
| NH Subtropics | 8% | 19% | 88% | 23% |
| Equatorial | 12% | 13% | 24% | 15% |
| SH Subtropics | 20% | 21% | 65% | 36% |
| SH High Latitudes | 6% | 6% | 28% | 5% |

**Table S6**  Seasonal RMSE mean between ensemble of products and models or select models over five regions.

|  |  |  |
| --- | --- | --- |
|  | Models | Select Models |
| Northern High Latitudes | 0.47 | 0.37 |
| Northern Subtropics | 0.12 | 0.09 |
| Equatorial | 0.04 | 0.04 |
| Southern Subtropics | 0.29 | 0.22 |
| Southern High Latitudes | 0.79 | 0.51 |

**Table S7** Correlations for detrended CO2 flux time series, between the product ensemble mean and that from all models and only select models. Values in bold are significant at the 95% confidence level (student t-test with p<0.05).

|  |  |  |
| --- | --- | --- |
|  | Products: Models | Products: Select Models |
| Global | **0.71** | **0.64** |
| N High Latitudes | 0.25 | 0.06 |
| N Subtropics | **0.86** | **0.82** |
| Equatorial | **0.85** | **0.86** |
| S Subtropics | **0.50** | **0.53** |
| S High Latitudes | 0.22 | 0.11 |