Seasonal Variability of Surface Ocean pCO_2 and Air-Sea CO_2 flux in the Continental Shelf of the US East Coast

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Study Objectives

- Develop an empirical surface ocean pCO_2 algorithm based on physical and biological proxy parameters (SST and Chl-a)
- Construct maps of pCO_2 and sea-air CO_2 flux for the US East Coast
- Analyze the physical-biogeochemical interactions that control phytoplankton blooms and how they affect the uptake of atmospheric CO_2
- Analyze the effects of the solubility and biological pumps on the surface-ocean pCO_2 variability

Data Sources and Methodology

- MODISA (SST, Chl-a) and SeaWiFS (Chl-a) products
- 3D Ocean model products (SST, SSS, pCO_2, air-sea CO_2 flux) and CCMP Winds
- *In situ* carbon data from available sources (underway pCO_2 and station data)
- Multiple regression of observed pCO_2 vs. proxy *in situ* parameters
- Algorithm application using satellite-based products, evaluation with in situ data and comparisons with numerical model simulations (ROMS NENA modeling system)

Study Domain and Available Ocean pCO_2 Data

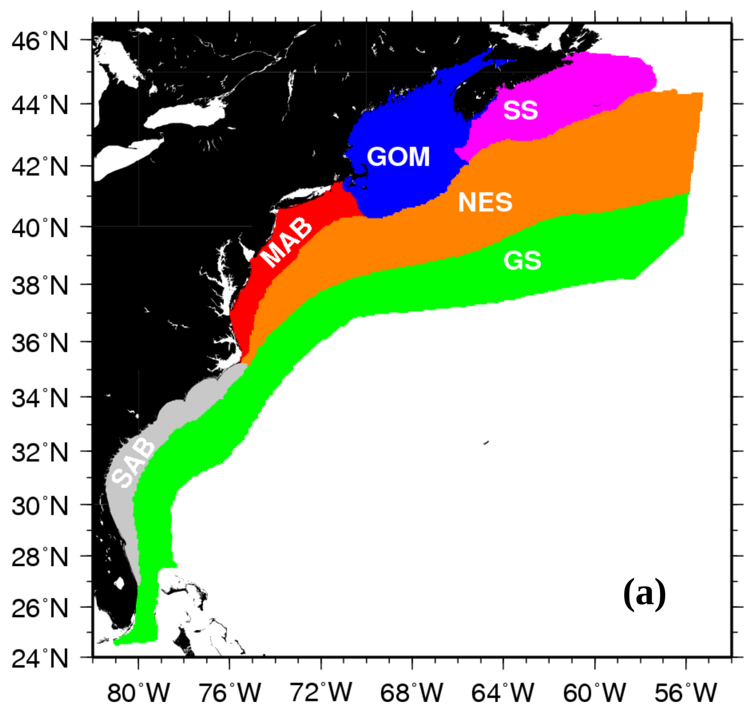


Fig. 1a. Study domain showing the six sub-regions analyzed: Mid Atlantic Bight (MAB), South Atlantic Bight (SAB), Gulf of Maine (GOM), Gulf Stream (GS), Northeast Shelf (NES), and Scotian Shelf.

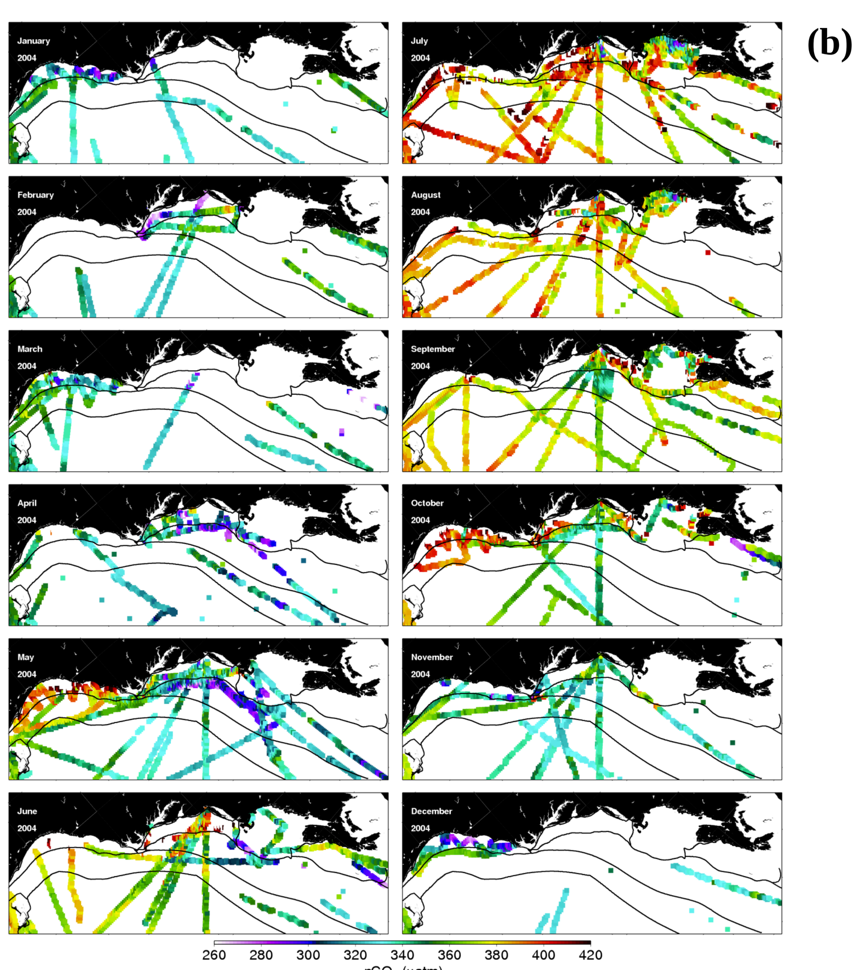
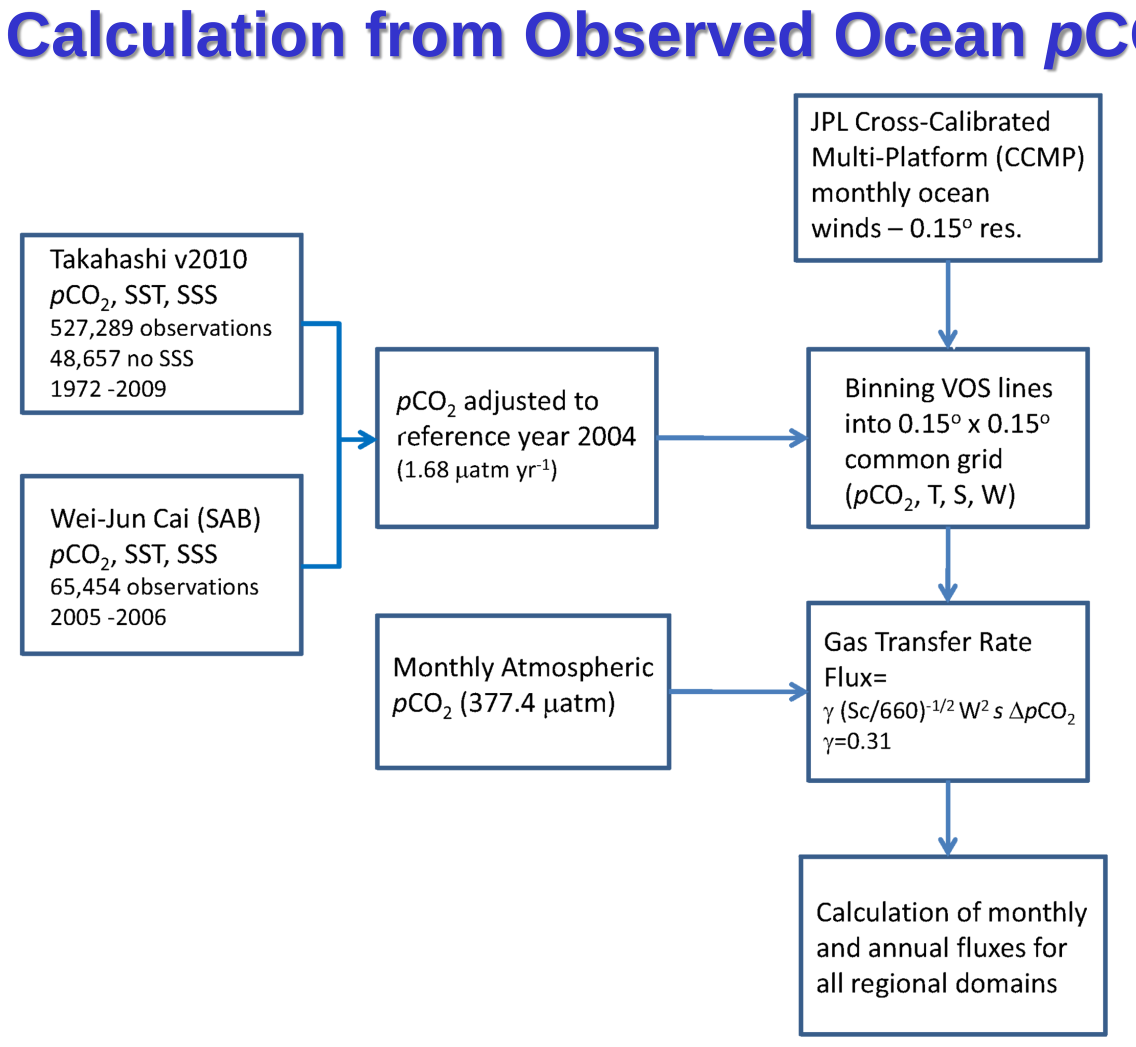


Fig. 1b. Monthly distribution of available underway surface ocean pCO_2 within the study region. The data originate from version 2010 of Takahashi's pCO_2 database and was binned into 0.15º×0.15º grid cells and adjusted to reference year 2004.

Flux Calculation from Observed Ocean pCO_2



- Use of monthly surface ocean pCO_2 and SST data, in conjunction with MODIS Aqua monthly Chl-a product to derive a satellite-based ocean pCO_2. Coefficients were derived for each season.
- Algorithm equation: fCO_2=a + b*lon + c*lat +d*SST + e*SST^2 + f*Chl-a + g*log$_{10}$(Chl-a)
- The above equation was used to generate pCO_2 maps. Air-sea CO_2 flux was estimated following the methodology described in the above flow chart.
- An expansion of the data sets will be required for algorithm improvement in regions of poor spatial and temporal coverage. Also, further analysis is planned towards algorithm accuracy improvement, including regional algorithm tuning and the use of other satellite proxy variables (CDOM absorption and POC, for example)
- Annual fluxes were estimated in two ways: (1) annual mean values were determined using both data and algorithm values at bins where data were available and the results multiplied by the total area (Table 1), and (2) by the summation of algorithm and model flux estimates (Table 2) for all bins within each region for all time steps in the model (3 days) and algorithm (monthly).
- Method 1 and 2 produce closer estimates where spatial and temporal resolution in data sampling are better (such as in the SAB where cruises were designed for that purpose). Flux estimates vary considerably in areas of poor data coverage.

Acknowledgements: We want to acknowledge the NASA Ocean Biology and Biogeochemistry Program for supporting this work under the USECoS project. We are also thankful to all the agencies, universities, and scientists who made the *in situ* data sets available to the community and that are being used in this study.

Scatter Plots of Monthly Surface Ocean pCO_2: Model and Algorithm Versus Observations

Algorithm vs. Observations

Model vs. Observations

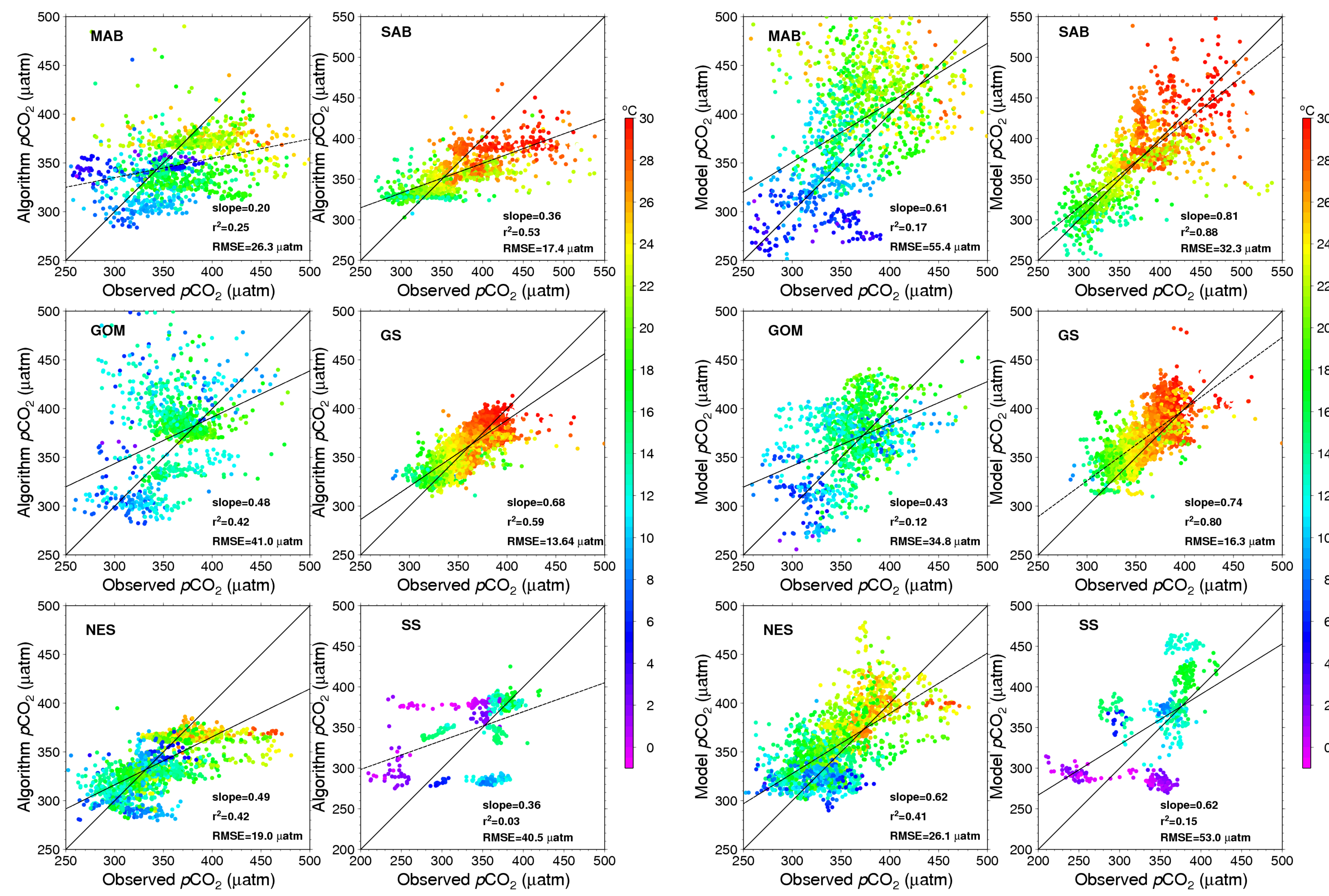


Fig. 4. Scatter plots of model vs. observed, and algorithm versus observed surface ocean pCO2. The color bar represents SST from observations.

Seasonal Variability of Surface Ocean pCO_2 and Annual CO_2 Flux

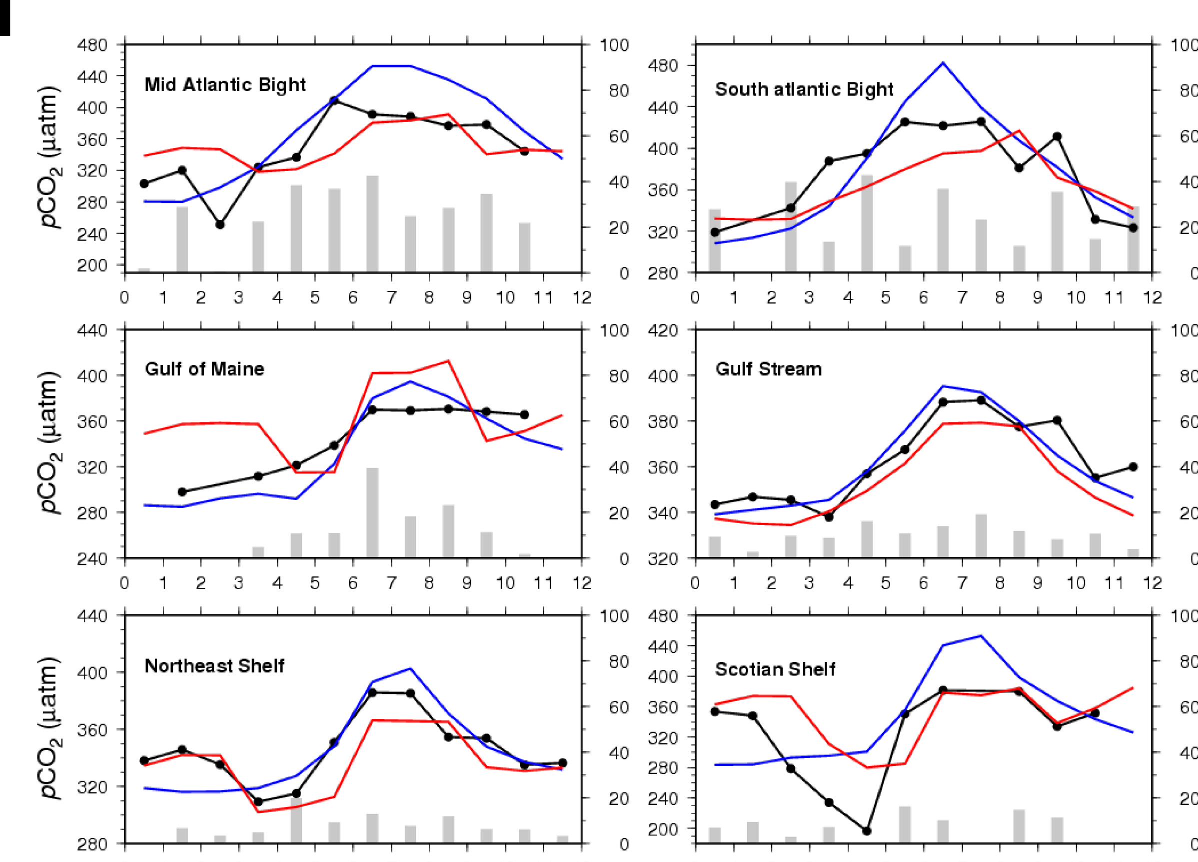


Fig. 2. Seasonal variability of surface ocean pCO_2 for each regional domain derived from observations (black line with circles), algorithm (red lines), and model (blue lines). The vertical gray bars indicate the percentage of data available for each month in each region.

Seasonal cycles of surface ocean pCO_2 derived from data, algorithm, and model are in best agreement in the MAB, SAB, and GS where data coverage is more homogeneous in time and space,. This is also reflected in the CO_2 flux estimates.

Scatter plots in Fig. 4 also show better agreement in the MAB, SAB, and GS, albeit the scatter is larger during spring and summer in the MAB and SAB when SSTs are warmer, mixed layer depths are shallower, and phytoplankton productivity increases and becomes spatially variable, as seen in satellite imagery.

The surface ocean pCO_2 data were derived from a multi-decadal database of underway observations and adjusted to a reference year (2004) assuming a 1.68 µatm yr^{-1}. Therefore, the scatter plots shown in Fig. 4 are considered a 'pseudo' matchup and some of the observed scatter may originate from the above assumption.

Fig 3. Maps of 2004 sea-air CO_2 flux for 2004 derived from algorithm and model.

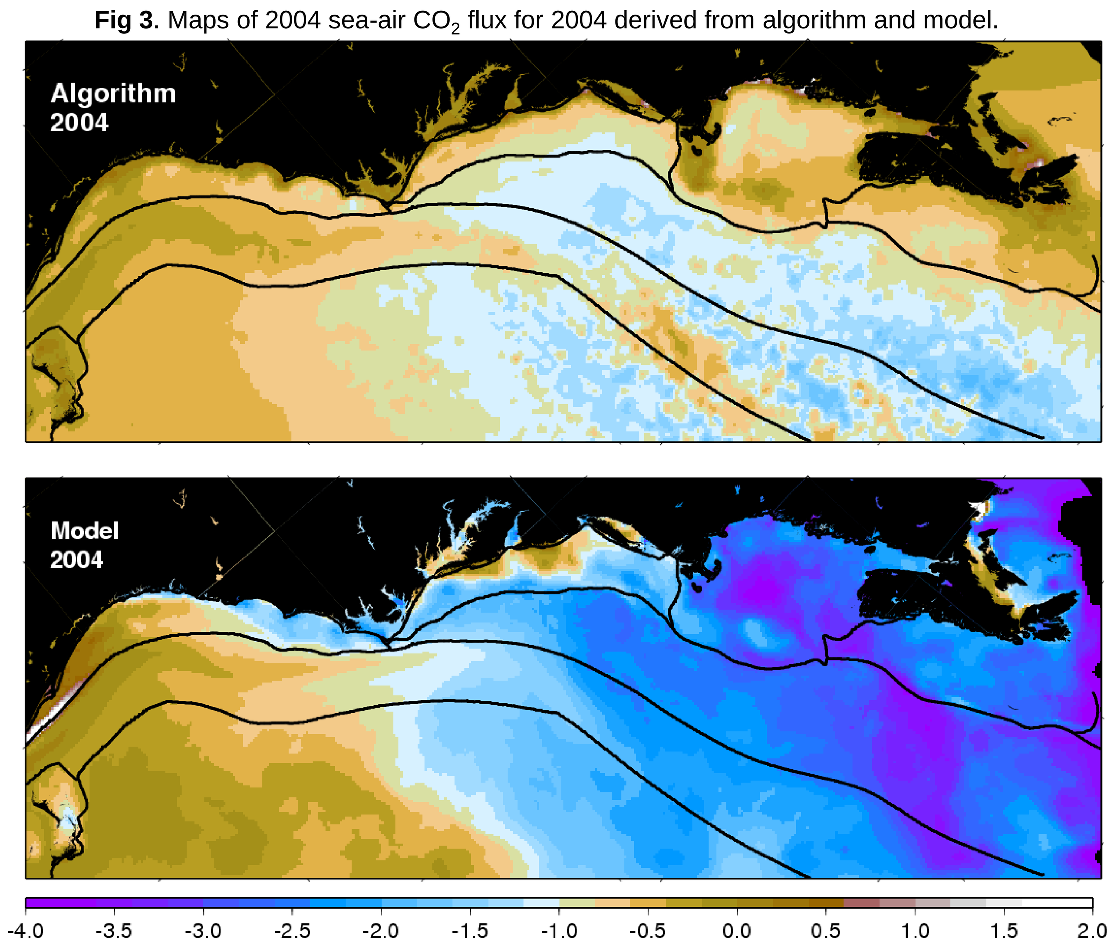


Table 1. Air-sea CO_2 flux estimates for all 6 regions based on data and algorithm (annual mean times total area, including only locations where in situ data are available).

Region	Area 10^{10} m^2	Data TgC yr^{-1}	Algorithm TgC yr^{-1}
MAB	8.6	2.6±0.5	2.1
SAB	9.2	0.7±0.3	1.5
GOM	16.7	3.8±0.8	3.0
GS	55.2	10.1±1.6	18.4
NES	45.5	13.4±1.8	19.0
SS	12.1	5.3±0.8	2.2

Table 2. Air-sea CO_2 flux estimates for all 6 regions based on model and algorithm (including all grid points and time steps).

Region	Area 10^{10} m^2	Model TgC yr^{-1}	Algorithm TgC yr^{-1}
MAB	8.6	1.4	0.8
SAB	9.2	0.7	0.5
GOM	16.7	5.4	1.0
GS	55.2	9.6	5.7
NES	45.5	14.5	6.3
SS	12.1	3.8	0.8

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