B216

Simulated flux of atmospheric CO2 into the Seto Inland Sea using a high-resolution biogeochemical model

○Jae-Soon JEONG, Han Soo LEE, Gandhi NAPITUPULU, Nobuhito MORI

The ocean is one of the major global-scale reservoirs capable of capturing and storing atmospheric carbon dioxide. Atmospheric CO_2 enters the ocean through air–sea gas exchange and is subsequently sequestered via physical circulation, chemical buffering within the carbonate system, and biological processes such as the biological pump.

Seagrass meadows further enhance atmospheric CO_2 uptake by lowering surface-water pCO_2 through intense photosynthesis and by sequestering carbon in sediments as blue carbon. In Japan, seagrass restoration has been recognized as a key blue carbon strategy that integrates climate change mitigation, coastal ecosystem restoration, and sustainable coastal management, particularly in semi-enclosed seas such as the Seto Inland Sea (SIS).

The SIS is a shallow semi-enclosed sea located in western Japan, covering an area of approximately 23,000 km², with a length of 450 km and an average depth of about 38 m (Lee et al., 2015). In recent years, a hydrodynamic ocean circulation model based on SCHISM has been applied to the SIS (Jeong & Lee, 2023). In this study, the circulation model was coupled with the biogeochemical model COSINE (Chai et al., 2002) to reproduce red tide events that occurred in Osaka Bay. Air–sea CO_2 fluxes were subsequently extracted to investigate the spatiotemporal patterns of carbon dioxide exchange between the ocean and the atmosphere in the SIS.

The COSINE model was simulated for spring 2016, targeting a red tide event reported in March by Japan's Fisheries Agency. The simulated surface concentration of small phytoplankton, identified as the primary cause of red tides, showed high concentrations consistent with reported observations at HG (Hyogo) and OS (Osaka), shown in Figure 1B.

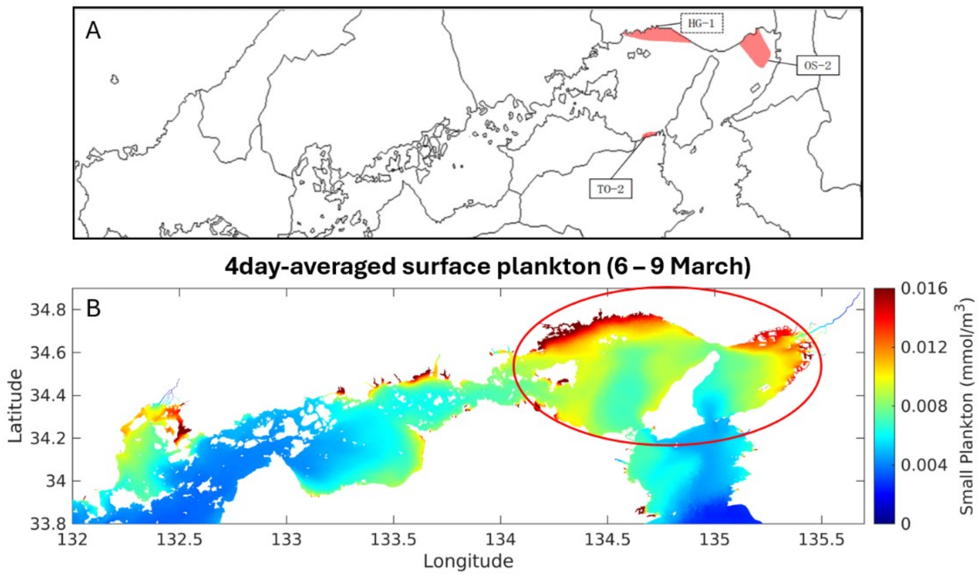

Figure 1. (A) Spatial distribution of red tide occurrences reported by Japan's Fisheries Agency, and (B) simulated surface-layer concentration of small phytoplankton from the COSINE model.

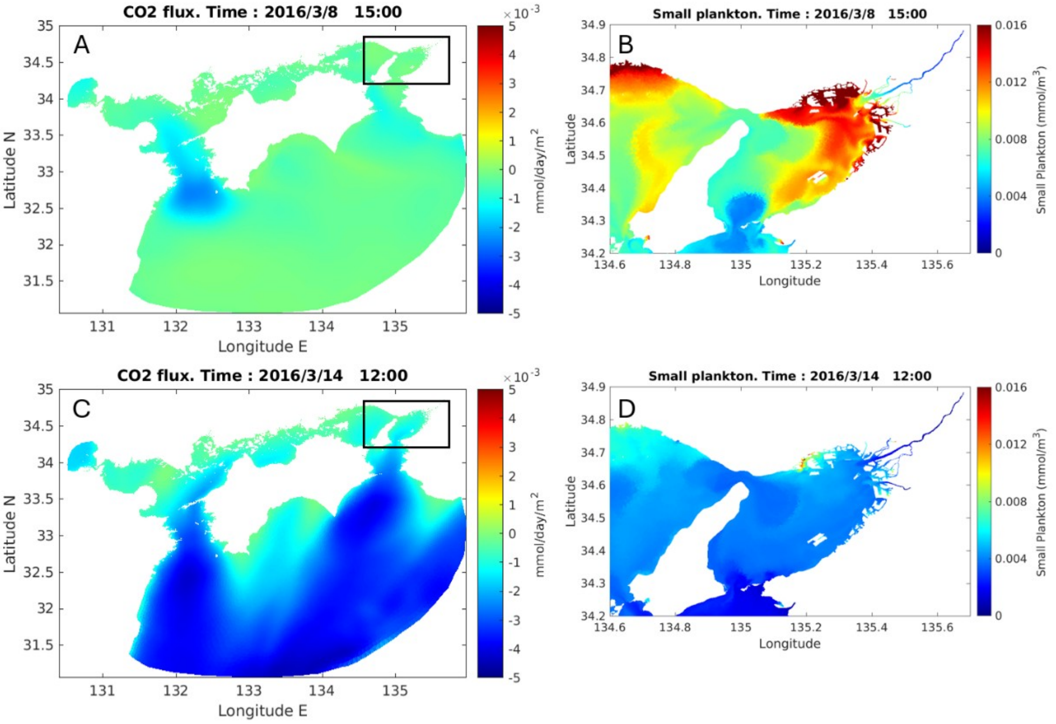

Figure 2. Air–sea CO_2 fluxes (positive values indicate ocean-to-atmosphere fluxes, while negative values indicate atmospheric CO_2 uptake by the ocean) during (A) the red tide period and (C) a high-flux period. (B) and (D) show the corresponding surface concentrations of small phytoplankton for the same periods.

The calculated air–sea CO_2 fluxes were generally negative, indicating a net influx of atmospheric CO_2 into the ocean (Figure 2A and 2C). This seasonal pattern in March is consistent with global satellite-based observations at mid-latitudes. (Shaik et al., 2025). However, the local distribution of CO_2 fluxes exhibited patterns largely independent of red tide occurrence. Although phytoplankton blooms reduced dissolved CO_2 concentrations through biological uptake, a corresponding enhancement of atmospheric CO_2 dissolution was not observed. Instead, increased CO_2 influx became dominant approximately one week after the red tide event (Figure 2C), primarily influenced by boundary conditions from the Pacific Ocean. The model results also indicate that the inner SIS is less affected by open-ocean conditions.

The COSINE model applied in this study simulates nutrient cycles (nitrate, silicate, ammonium, and phosphate), planktons (phyto- and zooplankton), dissolved gases (oxygen and carbon dioxide), and alkalinity. However, the model does not currently include the effects of seagrass or coral ecosystems, which can directly absorb dissolved CO_2 and sequester carbon in sediments. Ongoing work aims to quantify seagrass carbon sequestration rates in the SIS and to incorporate this process into the COSINE model, enabling an assessment of the contribution of coastal seagrass ecosystems to blue carbon storage.

References

Chai, F., Dugdale, R. C., Peng, T.-H., Wilkerson, F. P., & Barber, R. T. (2002). One-dimensional ecosystem model of the equatorial Pacific upwelling system. Part I: model development and silicon and nitrogen cycle. *Deep Sea Research Part II: Topical Studies in Oceanography*, *49*(13), 2713–2745. https://doi.org/https://doi.org/10.1016/S0967-0645(02)00055-3

Shaik, I., Nagamani, P. V, Pathakoti, M., & Srinivasa Rao, G. (2025). Assessment of Air–Sea CO2 Flux in Global Surface Oceans Using Satellite Data. *Sensing and Imaging*, *26*(1), 160. https://doi.org/10.1007/s11220-025-00676-5