

Benchmarking Global Ocean Carbon Cycle Models: Uncertainties in the anthropogenic CO₂ uptake estimation



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Scientific Objectives

- ✓ To evaluate the global ocean carbon cycle model performance using the International Ocean Model Benchmarking System (IOMB).
- ✓ To include/develop targeted metrics for the ocean carbon sink assessment for the Global Carbon Budget (GCB).

Methods

International Ocean Model Benchmarking System – version 3 (IOMBv3 – GCB version).

- ✓ A python-based open-source, multi-model validation tool for evaluating the overall performance of ocean carbon cycle models, using a set of statistical metrics including bias, RMSE, annual cycle phasing, spatial distribution etc (Fu et. al., 2022), developed from International Land Model Benchmarking (ILAMB) System (Collier et. al., 2018, Hoffman et. al., 2014).

- ✓ The relative errors (ϵ) are computed and transformed into normalised scores on the unit interval via an exponential function given by $s = e^{-\alpha\epsilon}$.

- ✓ The overall score ($S_{overall}$) for a given variable and the data is a composite of the suite of metric scores.

$$S_{overall} = \frac{S_{bias} + 2S_{rmse} + S_{phase} + S_{iav} + S_{dist}}{1 + 2 + 1 + 1 + 1}$$

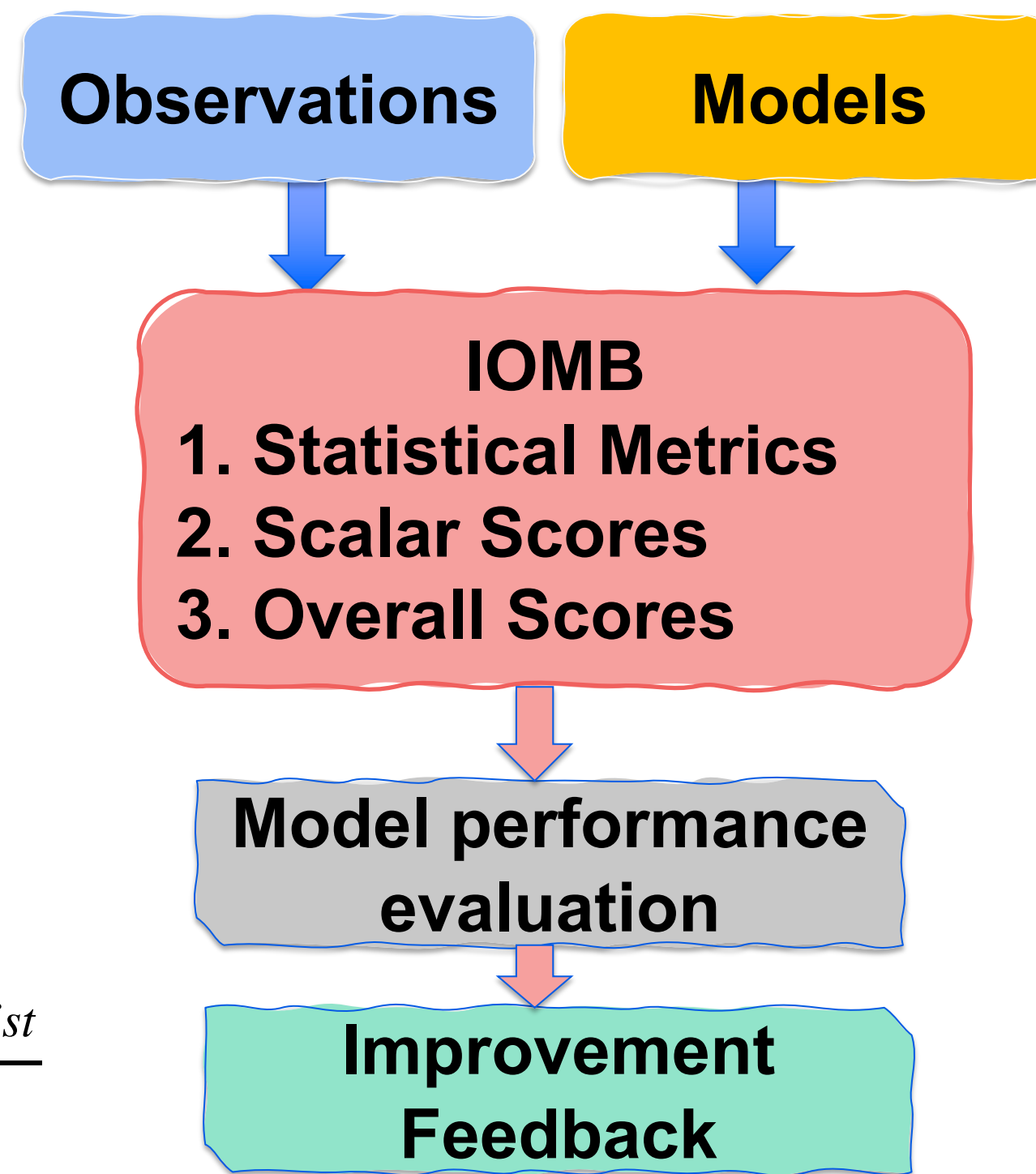


Figure 1. Schematic diagram of International Ocean Model Benchmarking System.

Present day mean of air-sea CO₂ flux from GCB models

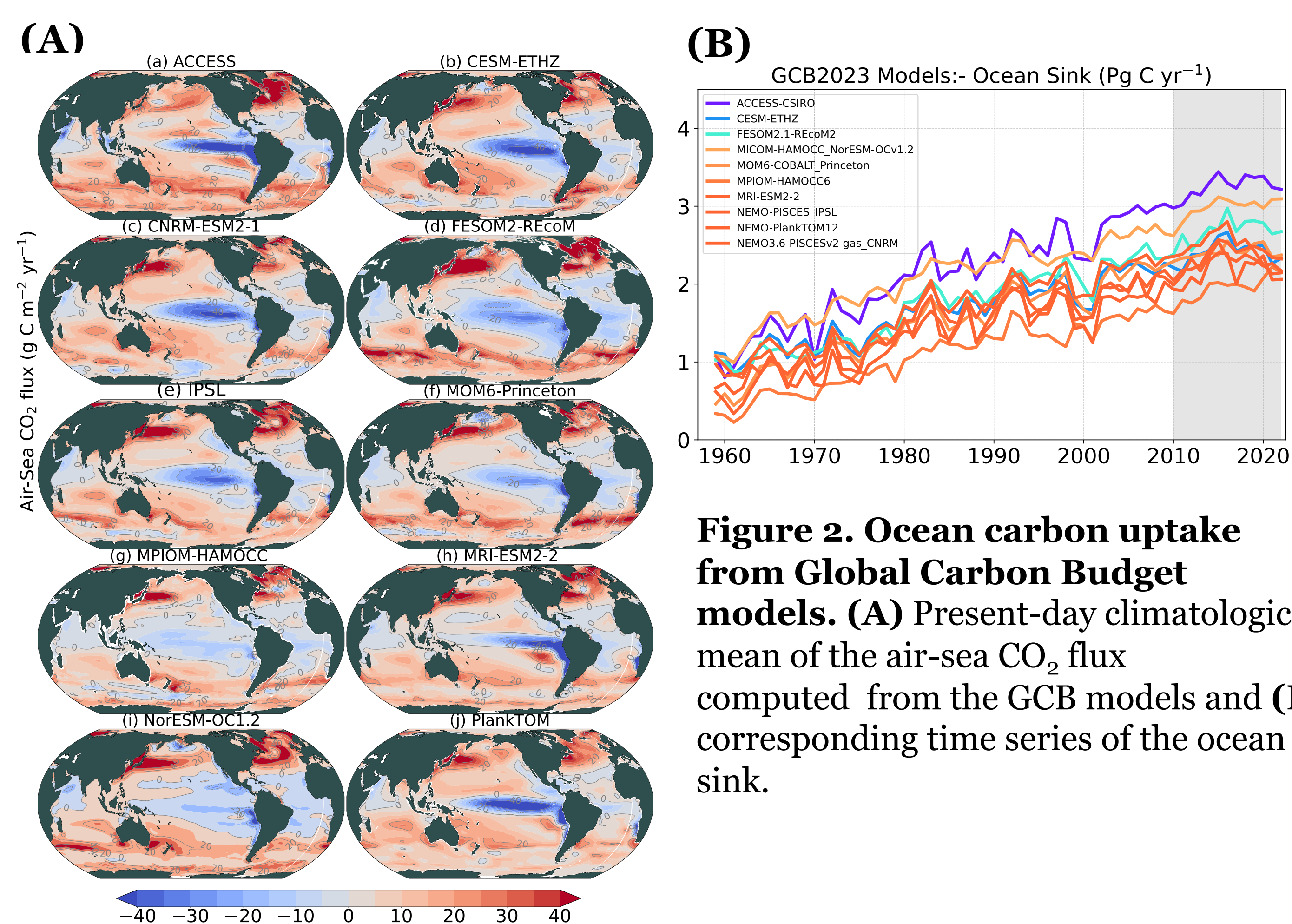
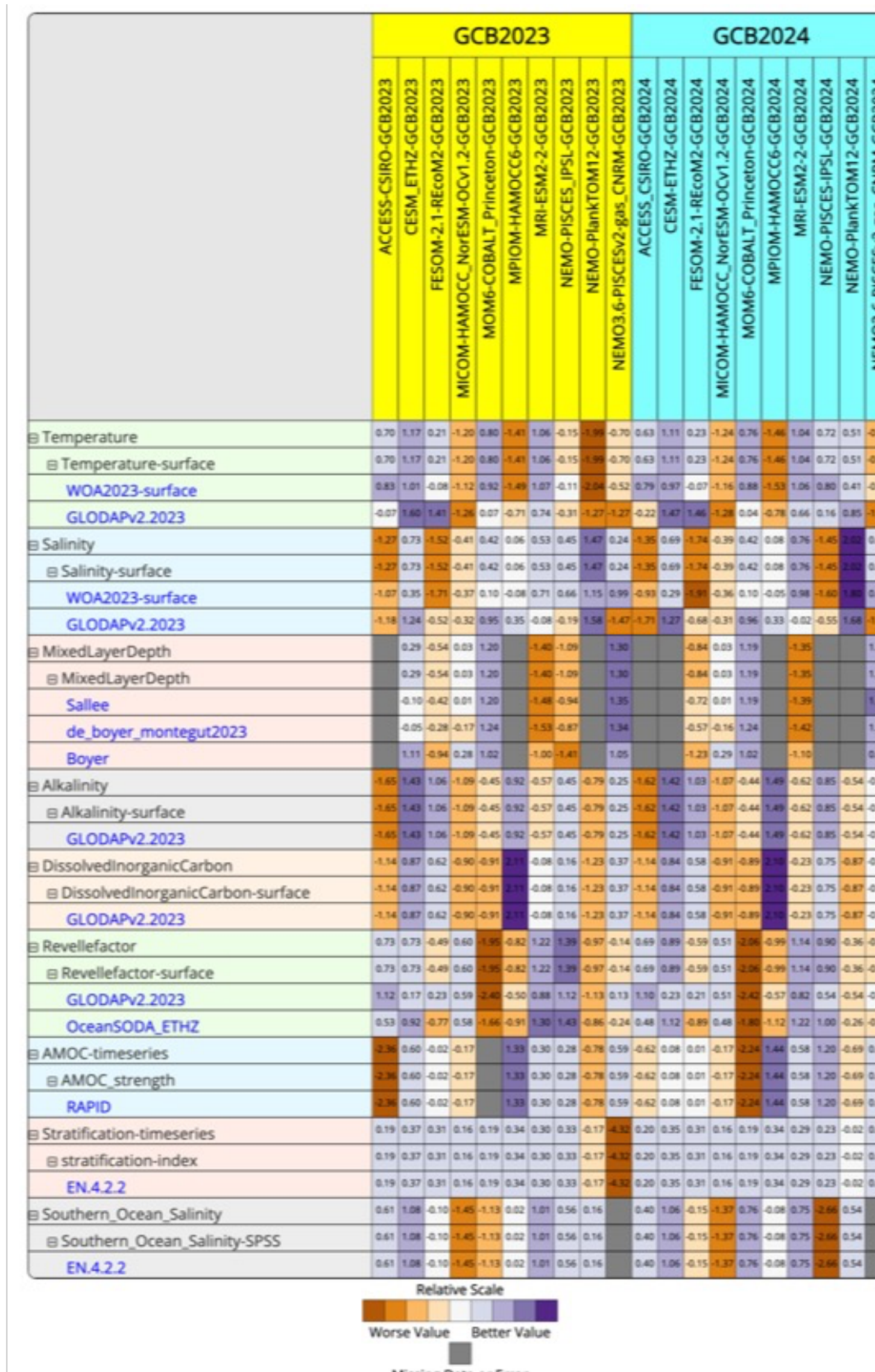


Figure 2. Ocean carbon uptake from Global Carbon Budget models. (A) Present-day climatological mean of the air-sea CO₂ flux computed from the GCB models and (B) corresponding time series of the ocean sink.

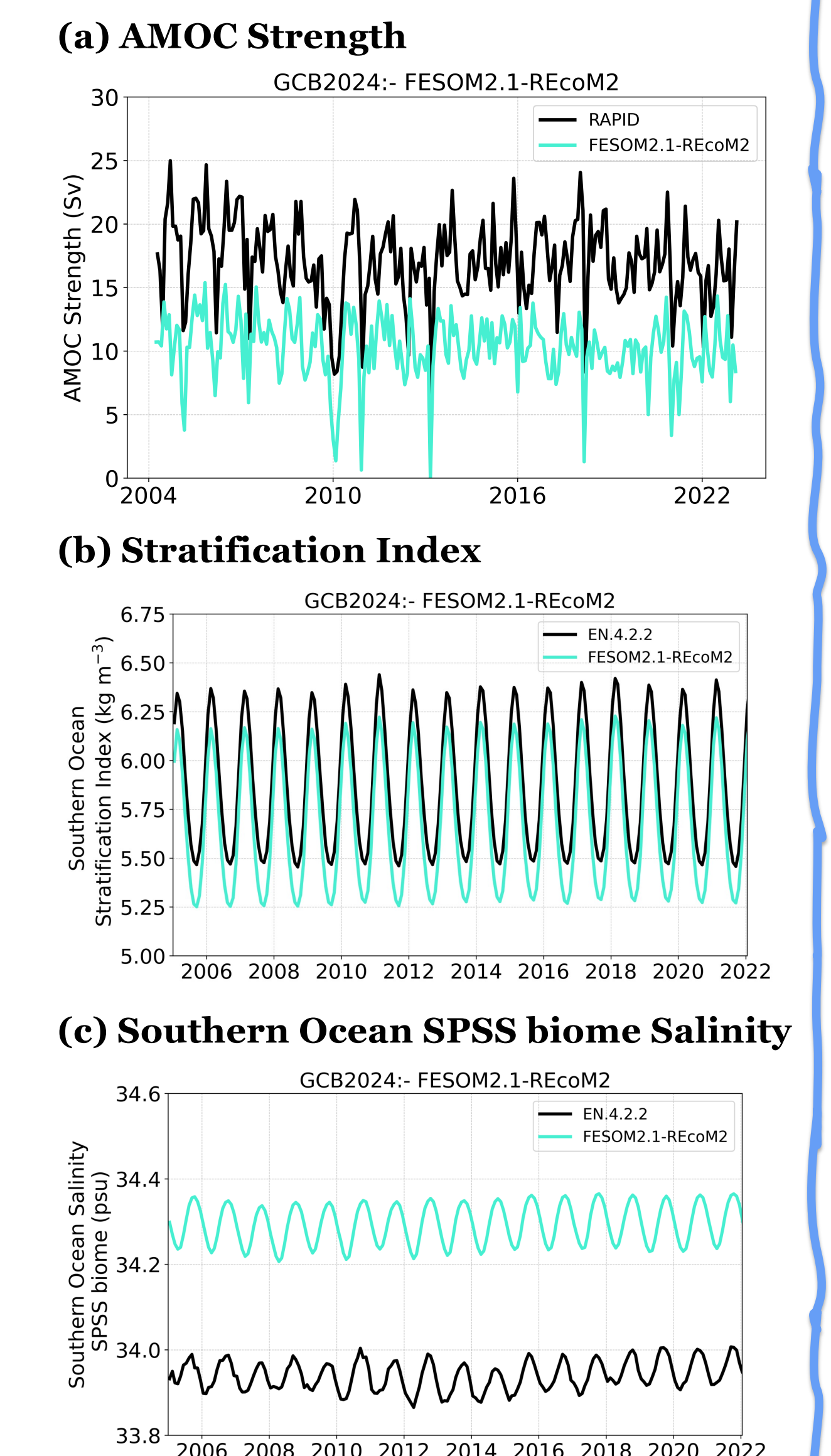
- ✓ Biases and uncertainties in the GCB model estimates of the ocean carbon sink may be due to imperfections in the representation of physical (e.g., transport, mixing) and biogeochemical processes, as well as in the forcing fields.

Preliminary Results

Overall Score of GCB models from the IOMBv3 – GCBv1



New target metrics in IOMB-GCB version



(d) Revelle Factor:

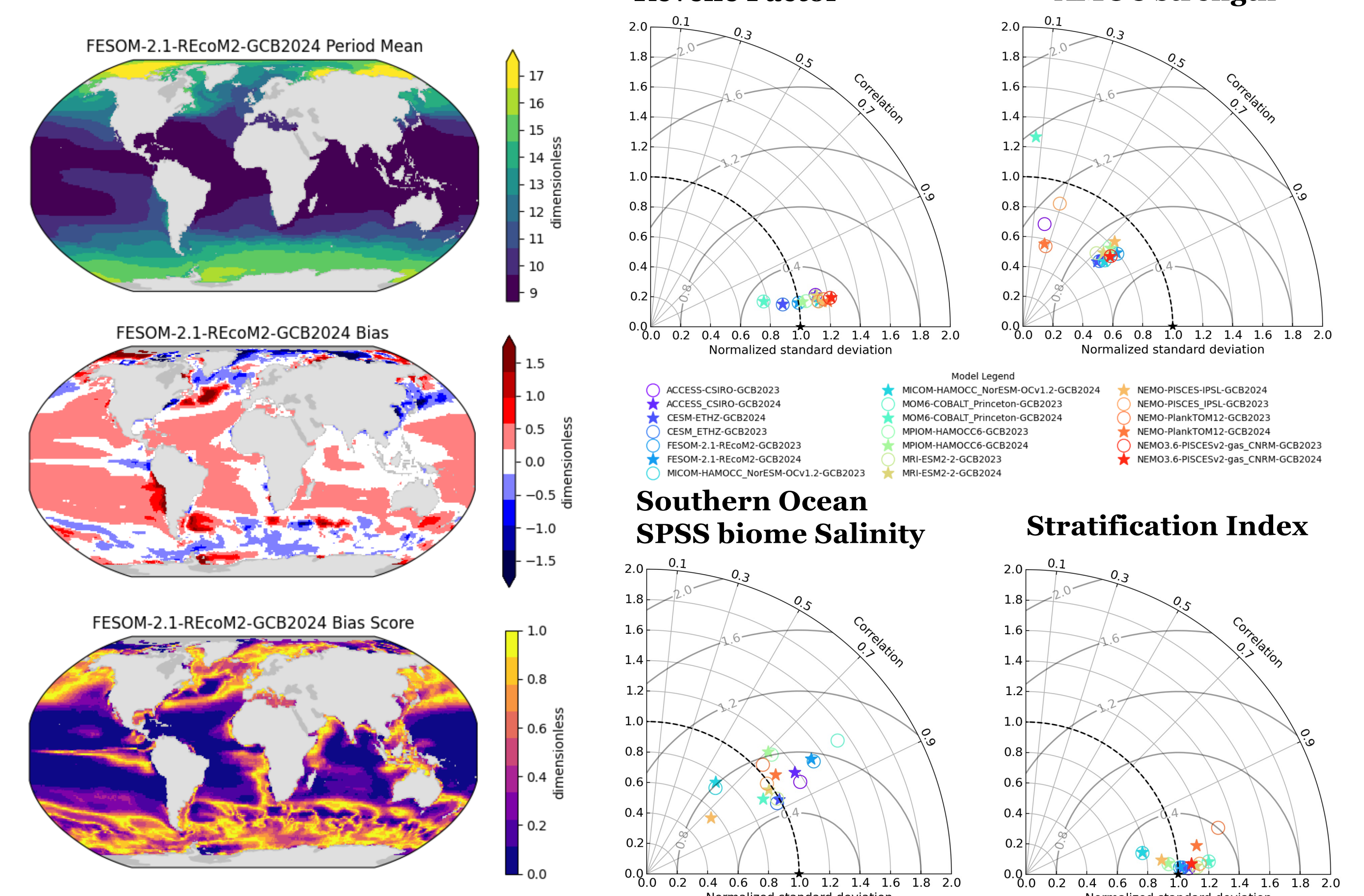


Figure 3. International Ocean Model Benchmarking System generated overall scores for GCB models: Summary of overall score for GCB models with special reference to physical drivers: Temperature, Salinity, Mixed layer depth, Dissolved Inorganic Carbon, Alkalinity, Revelle factor, AMOC strength, Stratification index, Southern ocean SPSS biome salinity, respectively. All scores are generated via validating against WOA/GLODAPv2.2023 observations. All scores are relative to the corresponding models in the row. Grey colour represents no data available.

Summary & Outlook

- ✓ The study evaluates the overall performance of the GCB2023 and GCB2024 models as a prototype for tracking improvements in model performance.
- ✓ These are the first results with the new version of IOMB (v3)
- ✓ Targeted metrics, such as AMOC strength, Stratification Index, Southern Ocean subpolar salinity and Revelle Factor are being added to evaluate the models' anthropogenic CO₂ uptake. Next: interpretation.
- ✓ Future work is to add the relationship analysis and depth gradient analysis to IOMB3-GCBv1.

References:
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✓ Collier, N., Hoffman, F. M., Lawrence, D. M., Keppel-Aleks, G., Koven, C. D., Riley, W. J., et al. (2018). The International Land Model Benchmarking (ILAMB) system: Design, theory, and implementation. *Journal of Advances in Modeling Earth Systems*, 10, 2731–2754. <https://doi.org/10.1029/2018MS001354>
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