Comparisons across spatial scales combined with observational constraints improves understanding of the North American carbon balance

Foster, K.T., Sun, W., Shiga, Y.P., Mao, J., & Michalak, A.M. (2024). Multiscale assessment of North American terrestrial carbon balance. Biogeosciences, doi:10.5194/bg-21-869-2024

NASA CMS CARBON MONITORING SYSTEM

NORTH AMERICAN CARBON PROGRAM

Science Question

- How does the consistency across carbon uptake estimates vary as a function of spatial scale, ranging from 1° × 1° to the North American continent?
- Is ensemble spread (consistency across models) a useful proxy for estimate accuracy (agreement between model estimates and reality)?

Analysis

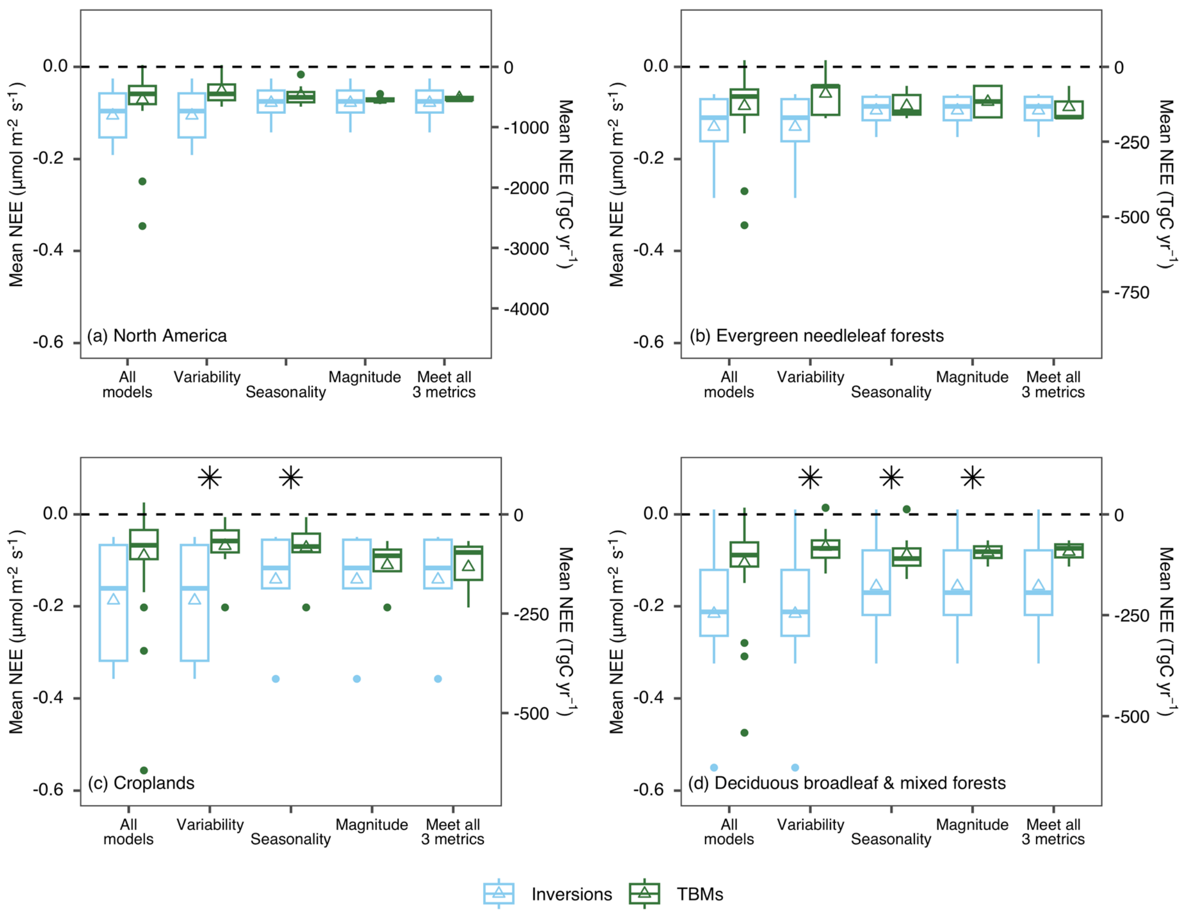
- We compared estimates from ensembles of bottom-up, terrestrial biosphere models, and top-down, atmospheric inversions across spatial scales.
- We evaluated how consistency within ensembles as well as agreement between top-down and bottom-up estimates changes when models are filtered based on whether they can reproduce basic features of observed atmospheric CO_2 variability, magnitude, and seasonality.

Results

- Bottom-up models are more consistent in their carbon uptake estimates for most regions and at most scales, relative to top-down models.
- Filtering models based on their ability to reproduce basic features of observed atmospheric CO_2 increases the consistency across bottom-up models, but not for top-down models. This suggests that ensemble model spread is not a good measure of estimate uncertainty.
- The agreement between top-down and bottom-up models improves substantially when only those models that reproduce basic features of observed atmospheric CO_2 are included in ensembles.

Significance

Prior research has shown persistent uncertainties in bottom-up and top-down approaches, resulting in disagreement on the North American carbon balance. We show that multiscale assessment of bottom-up and top-down estimates, along with observational constraints, aids in identifying sources of uncertainty and improves ensemble consistency and accuracy.



Increased agreement between bottom-up and top-down models for North America (a) and major biomes (b-d). The spread in carbon uptake estimates across bottom-up (green) and top-down (blue) models and the average estimates (triangles) show improved agreement when models match atmospheric observations ('All models' vs 'Meet all 3 metrics'). Stars show statistically significant differences ($p<0.05$) between the spread of the bottom-up and top-down models.

NASA CMS CARBON MONITORING SYSTEM

Comparisons across spatial scales combined with observational constraints improves understanding of the North American carbon balance

Foster, K.T., Sun, W., Shiga, Y.P., Mao, J., & Michalak, A.M. (2024). Multiscale assessment of North American terrestrial carbon balance. Biogeosciences, doi:10.5194/bg-21-869-2024

NORTH AMERICAN CARBON PROGRAM

Full citation: Foster, K.T., Sun, W., Shiga, Y.P., Mao, J., & Michalak, A.M. (2024). Multiscale assessment of North America terrestrial carbon balance. Biogeosciences, doi:10.5194/bg-21-869-2024

Funding support: This study was funded by NASA through the Carbon Monitoring System (grant no. 80NSSC18K0165) and the Terrestrial Ecology programs (grant no. 80NSSC22K1253).

Abstract: Comparisons of carbon uptake estimates from bottom-up terrestrial biosphere models (TBMs) to top-down atmospheric inversions help assess how well we understand carbon dioxide (CO_2) exchange between the atmosphere and terrestrial biosphere. Previous comparisons have shown varying levels of agreement between bottom-up and top-down approaches, but they have almost exclusively focused on large, aggregated scales (e.g., global or continental), providing limited insights into reasons for the mismatches. Here we explore how consistency, defined as the spread in net ecosystem exchange (NEE) estimates within an ensemble of TBMs or inversions, varies with at finer spatial scales ranging from $1° \times 1°$ to the continent of North America. We also evaluate how well consistency informs accuracy in overall NEE estimates by filtering models based on their agreement with the variability, magnitude, and seasonality in observed atmospheric CO_2 drawdowns or enhancements. We find that TBMs produce more consistent estimates of NEE for most regions and at most scales relative to inversions. Filtering models using atmospheric CO_2 metrics causes ensemble spread to decrease substantially for TBMs, but not for inversions. This suggests that ensemble spread is likely not a reliable measure of the uncertainty associated with the North American carbon balance at any spatial scale. Promisingly, applying atmospheric CO_2 metrics leads to a set of models with converging flux estimates across TBMs and inversions. Overall, we show that multiscale assessment of the agreement between bottom-up and top-down NEE estimates, aided by regional-scale observational constraints is a promising path towards identifying fine-scale sources of uncertainty and improving both ensemble consistency and accuracy. These findings help refine our understanding of biospheric carbon balance, particularly at scales relevant for informing regional carbon-climate feedbacks.