Carbon cycle uncertainty in the Alaskan Arctic

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Objectives:

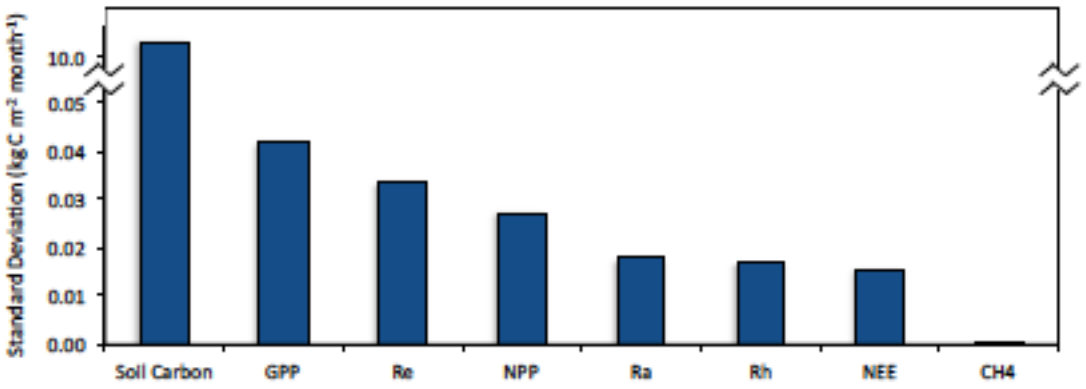
- This study provides a baseline of terrestrial carbon cycle uncertainty in the Alaskan Arctic.
- The authors use 40 terrestrial biosphere models from four recent model intercomparison projects.
- The intercomparison projects used were the North American Carbon Program (NACP) regional, NACP site, Trends in net land atmosphere carbon exchanges (TRENDY), and the Wetland and Wetland CH_4 Inter-comparison Models Project (WETCHIMP).
- AmeriFlux sites were included to provide a quantitative comparison to simulation results.
- The objective of this analysis was to compile and quantify predictive uncertainty in terrestrial carbon cycle dynamics for Alaska, focusing on statistical quantification for the Alaskan Arctic (North Slope) but providing regional maps as well.
- This study also evaluated the uncertainties contributing to divergent model results, and the resultant multimodal variability in the carbon flux/stock estimation.
- The analysis was specifically designed for application to currently planned field campaigns to aide in justification and planning for geographic sampling decisions.

New Science:

- For the first time, this analysis quantified in a rigorous and community-inclusive approach the numerical uncertainties in carbon cycle for dynamics for Alaska.
- Unlike earlier studies, this study provides spatial distribution of uncertainties.
- The results expand the uncertainty quantification to four times as many carbon cycle variables across four times as many terrestrial biosphere models as previous studies.
- A unique feature of this analysis is the comparison of NACP regional and TRENDY.
- Spatial and temporal uncertainties in CO_2 fluxes, CH_4 fluxes and solid carbon stocks were large.
- Mean annual absolute uncertainty was largest for soil carbon then, in order, for gross primary production (GPP), ecosystem respiration (Re), net primary production (NPP), autotrophic respiration (Ra), heterotrophic respiration (Rh), net ecosystem exchange (NEE) and CH_4 flux.
- The uncertainties ranged from 14.0 +/- 9.2 kg C m^{-2} (soil carbon) to 2.25 +/- 4.02 g CH4 $m^{-2}y^{-1}$.
- The spatial patterns in mean annual NEE for statewide Alaska varied widely among models, essentially showing no consistency, and with almost all models having at least one other model showing the opposite pattern.
- Some models showed the entire region as a strong carbon sink, others as a strong carbon source, while others showed part of the region as source and part as sink, while others showed the opposite pattern of sink and source distribution.
- The mean Alaskan Arctic time-varying NEE was generally similar in timing across models, showing carbon sinks in the short growing season, and carbon sources in the winter.
- The time series for CH_4 in the Alaskan Arctic showed similar temporal patterns for most of the models, with CH_4 flux emissions year round for many models.
- Seasonal patterns were negligible for soil carbon; they were relatively constant throughout the year.
- For site level evaluation in Atqasuk and Barrow, models did not capture the seasonal cycle well at either site relative to in situ measured NEE, although observed NEE tended to be contained within the multi-model uncertainty.
- Most models do not represent well the fast and slow storage and turnover rates of soil carbon with depth.
- At least one model that performed well in the tropics performed poorly in this study; the results of this study have already been used to improve that model's performance.

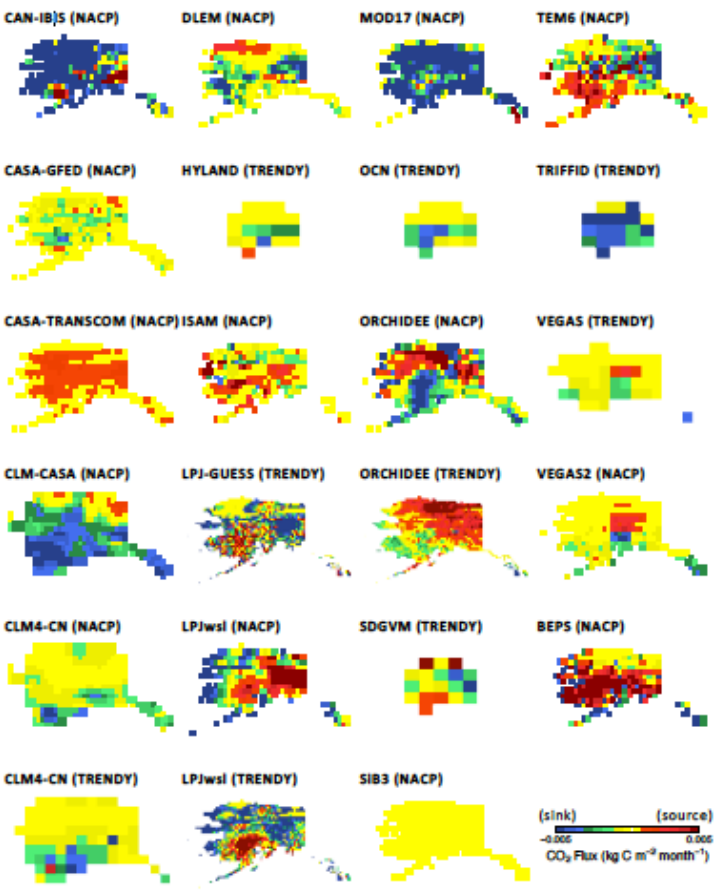
Significance:

- Climate change is leading to a disproportionately large warming in the high northern latitudes, but the magnitude and sign of the future carbon balance is highly uncertain.
- Point based measurements indicated that the Alaskan Arctic is currently a net CO_2 source to the atmosphere, but it is still impossible to determine with certainty whether or not it is a net sink or source, let alone predict future CO_2 flux sign and magnitude.
- The results of this study are fundamental to future research in the Alaskan Arctic and boreal region to reduce uncertainties in the Arctic and boreal carbon cycle.
- This assessment of carbon cycle uncertainties may be used as a baseline for the improvement of experimental and modeling activities, as well as a reference for future trajectories in carbon cycling with climate change in the Alaskan Arctic and larger boreal region.
- The large variation between measurement and model output is significant and noteworthy.
- The significant disagreement in modeled solid carbon stocks suggests a major area of focus for model development given the potential impact of mobilized Arctic soil carbon with climate change.
- This analysis can be used to carefully evaluate the stress sensitivities and representations of models that perform poorly in this region but perform well elsewhere, to improve the model overall.
- The next step in reducing uncertainties is to bench-mark the models used in this analysis against the wealth of data that will be generated by current and upcoming field campaigns.
- Further work should focus not only on reducing climate uncertainty impacts on the Arctic and boreal carbon cycle, but also focus on understanding and estimating the current state of the Arctic and boreal carbon cycle.
- This study is the largest-ever multi-terrestrial biosphere model assessment of carbon dynamics and associated uncertainties for the Alaskan Arctic and boreal regions.



(Figure 9 pg 4281)

Multi-model uncertainty for all carbon components in the Alaskan Arctic (North Slope): (1) net ecosystem exchange (NEE) of CO_2 between land and atmosphere; (2) net primary production (NPP); (3) atmospheric respiration (Ra); (4) gross primary production (GPP); (5) total ecosystem respiration (Re); (6) CH_4 flux; (7) heterotrophic respiration (Rh); and (8) soil carbon.



(Figure 2 on page 4277)

Mean annual (2003) net CO_2 flux for Alaska. Model output was part of the TRENDY (common forcing) and NACP regional.