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Evaluation of terrestrial pan-Arctic carbon cycling using a data-assimilation system

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There is a significant knowledge gap in the current state of the terrestrial carbon (C) budget. Recent studies have highlighted poor understanding particularly of C pool transit times, and whether productivity or biomass dominate these biases. The Arctic, accounting for approximately 50% of the global soil organic C stocks, has an important role in the global C cycle. Here, we use the CARDAMOM data-assimilation system to produce pan-Arctic terrestrial C cycle analyses for 2000-15. This approach avoids using traditional plant functional type or steady-state assumptions. We integrate a range of data (soil organic C, leaf area index, biomass, and climate) to determine the most likely state of the high latitude C cycle at a 1° x 1° resolution, and also to provide general guidance about the controlling biases in transit times. On average, CARDAMOM estimates regional mean rates of photosynthesis of 565 g C m-2 yr-1 (90% confidence interval between the 5th and 95th percentiles: 428, 741), autotrophic respiration of 270 g C m-2 yr-1 (182, 397) and heterotrophic respiration of 219 g C m-2 yr-1 (31, 1458), suggesting a pan-Arctic sink of -67 (-287, 1160) g C m-2 yr-1, weaker in tundra and stronger in taiga. However, our confidence intervals remain large (and so the region could be a source of C), reflecting uncertainty assigned to the regional data products. We show a clear spatial and temporal agreement between CARDAMOM analyses and different sources of assimilated and independent data at both pan-Arctic and local scales, but also identify consistent biases between CARDAMOM and validation data. The assimilation process requires clearer error quantification on LAI and biomass products to resolve these biases. Mapping of vegetation C stocks and change over time, and soil C ages linked to soil C stocks is required for better analytical constraint. Comparing CARDAMOM analyses to global vegetation models (GVM) for the same period, we conclude that transit times of vegetation C are inconsistently simulated in GVMs due to a combination of uncertainties from productivity and biomass calculations. Our findings highlight that GVMs need to focus on constraining both current vegetation C stocks and net primary production, to improve process-based understanding of C cycle dynamics in the Arctic.