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Low and rising atmospheric carbon dioxide during the evolution of aerosols from land plants

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One of the largest uncertainties in current and deep time climate change is the radiative forcing from aerosols and their interaction with clouds. Overall aerosol – cloud interactions contribute to cool the current climate. Beside the anthropogenic aerosol contributions there are two main types: inorganic and biogenic. The biogenic aerosol contribution from terrestrial vegetation likely underwent a significant increase when land plants evolved and increased in dominance from the Ordovician through Devonian. The permanent change in radiative forcing from aerosols-cloud interactions likely influenced the long-term carbon cycle, leaving a detectable imprint.

Here, we probe the atmospheric CO_2 levels during the Ordovician–Silurian when plants gained prominence on land. The CO_2 levels are estimated using the Bryocarb model [1], $d^{13}C$ of bryophyte spores [2], and calculated atmospheric $d^{13}C$ based on carbonate $d^{13}C$ records and regional surface temperatures from coupled ocean-atmosphere general circulations models. Using Monte Carlo error propagation, the reconstructed CO_2 levels correspond to estimates in [2] but they are much lower than other previous CO_2 estimates and expectations derived from climate proxies. Our analysis of published $d^{13}C$ in marine organic extracts and biomarkers through the Cambrian – Silurian independently supports long-term low CO_2 levels during the Ordovician followed by rising levels through the Silurian. Noteworthy, we also find a temporary but modest increase in CO_2 during the Hirnantian glaciation interval.

Finally, we model the plant induced aerosol-cloud interaction using a simple aerosol-cloud climate model coupled to a carbon cycle model. These model results indicate that early plant evolution likely caused more aerosol-cloud radiative cooling of Earth, which changed the silicate weathering setpoint, in turn permitting a long-term increase in CO_2.

[1] Fletcher, Brentnall, Quick, Beerling (2006), Geochim. Cosmochim. Acta. 70(23), 5676-5691.

[2] Beerling, Nelson, Pearson, Wellman (2008), AGU Annual meeting.