Timescales and symmetry of land and ocean carbon sink responses to prior emissions

Charlie Koven, Sanderson, B. M., Brovkin, V., Fisher, R., Hohn, D., Ilyina, T., Jones, C., Koenigk, T., Li, H., Lawrence, D., Lawrence, P., Liddicoat, S., Macdougall, A., Mengis, N., Nicholls, Z., O'Rourke, E., Romanou, A., Sandstad, M., Schwinger, J., Seferian, R., Sentman, L., Simpson, I., Smith, C., Steinert, N., Swann, A., Tjiputra, J., and Ziehn, T





It is difficult, when emissions are growing exponentially, to know the timescale on which sinks respond to emissions.



Friedlingstein et al., Global Carbon Budget 2024

Once we get off an exponential-like emissions pathway, the lags between the lags between emissions and sinks may start to become more clear



Koven et al, ERL, 2023

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flat10MIP: An emissions-driven experiment to diagnose the climate response to positive, zero, and negative CO2 emissions

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Response of ESMs to flat10MIP forcings: Atmospheric CO_2



Sanderson et al, 2024b

Response of ESMs to flat10MIP forcings: Land Sink



Sanderson et al, 2024b

Response of ESMs to flat10MIP forcings: Ocean Sink



Sanderson et al, 2024b

Land has a short memory of emissions, which can be quantified by fitting sinks as a lagged function of prior emissions. Using *flat10* and *flat10-zec* experiment, land sink is well explained by a single exponential-decay memory timescale of 1-15 years.



Ocean carbon sink responds on multiple timescales, with both a fast component (<10 years) and a slow component (>100 years) needed to approximate the response.



Are the carbon cycle dynamics really any different under negative emissions than under positive or zero emissions? I.e., if we use the same functional relationship from *flat10* and *flat10-zec*, and apply it to *flat10-cdr*, does it predict the land fluxes? For some models, yes.



Likewise in the ocean carbon cycle: some of the models show a strong carbon source under negative emissions late in *flat10-cdr* than would be predicted from the response in *flat10* and *flat10-zec*.



Conclusions

- We can use flat10MIP experiments to probe the timescales of response of the carbon cycle to emissions
- Land and ocean carbon sinks respond very quickly to changes in emissions, though ocean also has a long centennial-timescale memory
- The symmetry of carbon responses to positive and negative emissions is model-dependent. Some ESMs are very symmetric, others show stronger land and/or ocean sources under negative emissions than would be expected based on the response to positive and zero emissions.
- This is one part of the story for what governs ZEC and related pathdependency metrics of the relationship between GMST and cumulative emissions.

Thanks!