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Interactive comment on "Transient Dynamics of Terrestrial Carbon Storage: Mathematical foundation and Numeric Examples" *by* Yiqi Luo et al.

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Luo et al provide an excellent mathematical framework for studying the dynamics of the carbon cycle in terrestrial ecosystems. The focus on transient dynamics makes clear which aspects of carbon storage and sequestration are most important to consider in order to understand the functioning of forests are carbon reservoirs. The reduction of the models to a 3D parameter space is seemingly very useful for a mechanistic understanding of the effects of global change on terrestrial carbon storage.
The modeling assumptions could use further clarification. In particular, the assumption that short-term disturbances can be well represented by the matrix equation (assumption 5) and the assertion that this assumption is unlikely to affect the results need

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further support. Disturbances may be very important for the carbon cycling of terrestrial systems and can affect ecosystem dynamics and carbon cycling for decades, in addition to causing C fluxes that greatly exceed those from annual cycles. Presumably, disturbance events could be incorporated in the time varying factors u(t) and $\xi(t)$. However, there are a number of well-developed non-linear models for pest outbreaks that might violate the assumption that transfer between pools can be represented by a linear model (assumption 1) if outbreaks were to be incorporated into these factors.
While one aspect of pest outbreaks is a reduction in GPP or NPP, which may be sufficiently represented by u(t), even a linear approximation of the rapid change in the transfer of biomass between classes cannot be represented by this model without making the matrix A of transfer coefficients also time-dependent. One way this may be overcome is by setting limits on the timescale of applicability of this mathematical framework, so as to assume that transfer coefficients are not changing. Further, abiotic disturbances such as fire or disturbances that remove carbon from the ecosystem completely such as harvesting would be outside the scope of this model. The authors show that X'(t) in this model is the net ecosystem production (NEP), but non-biotic transformation from organic and inorganic carbon is not included in NEP, nor is transfer between ecosystems. This may just require a clarification of terminology in order to include fire, other abiotic oxidation, and harvesting in the $\xi(t)$ term of the model.
Finally, it may be useful to clarify on what scale the results apply. Based on the assumptions about linear decay smoothing small scale fluctuations and the neglect of lateral C fluxes, it seems important to point out that this is model applies only at the ecosystem scale. The parameters are calibrated based on one grid cell of the TECO model; would the same procedure be expected to scale up to larger spatial scales?
In the conclusion, the authors state that this model is consistent with complex dynamics including tipping points, which they say are "caused by multiple environmental forcing variables interacting with relatively simple internal processes over different temporal and spatial scales." Tipping point behavior crucially depends on non-linear dynamics and so seems inconsistent with this model. However, a clarification that this method

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can evaluate the transient dynamics in a given state but does not reproduce more complex behavior may be more accurate.

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