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On the emerging constraint for temperature sensitivity of tropical land carbon

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Cox et al. [1] found in simulation data of the C_4MIP study a linear relationship between the short term and long term temperature sensitivity of the tropical land carbon cycle across the participating Earth system models. As Cox et al. pointed out, combined with the observed temperature sensitivity of ENSO induced variations in atmospheric CO_2 growth rates, this model independent relationship can be used to derive a constraint on the otherwise not observable long term feedback strength between tropical climate and carbon cycle. But the status of this 'emergent constraint' is currently unclear: it has been corroberated [2] and rejected [3], both on the basis of CMIP5 simulation data. Moreover it is lacking a theoretical foundation. To overcome this situation, the present study analyses the relation between the short and longterm response of the tropical carbon cycle to temperature perturbations on the basis of linear multi-box models. For this class of models, a general relationship between short and long term sensitivities is derived mathematically. But this relationship lacks the necessary model independence. This model independence naturally arises when specializing to the case of a single-box model upon the additional assumption that tropical carbon turnover time is larger than the ENSO timescale. But the obtained relationship turns out to be quantitatively wrong when compared with results from C_4MIP and CMIP5 simulation results so that a more complex model structure seems to be a necessary ingredient to explain the observed relationship. Further investigation reveals that a model independent relationship can be obtained in several ways also in the multi-box case by invoking additional assumptions narrowing down the considered class of box models. Using data from C_4MIP and CMIP5, the realism of these additional assumptions is discussed. A pre-liminary result from this study is that from the viewpoint of linear box models no general explanation emerges why the C_4MIP and CMIP5 models should show the relationship found by Cox et al. [1]. On the contrary, the study may explain why 'outliers' off the suggested relationship are naturally to be expected – like the data point from the MPI-ESM in the study of Wenzel et al. [2].

[1] P. M. Cox et al., Sensitivity of tropical carbon to climate change constrained by carbon dioxide variability, Nature 494 (2013) 341-344.

[2] S. Wenzel et al., Emergent constaints on climate-carbon cycle feedbacks in the CMIP5 Earth system models, J. Geophysical Research: Biogeosciences 119 (2014) 794-807.

[3] J. Wang et al., To what extent can interannual CO 2 variability constrain carbon cycle sensitivity to climate change in CMIP5 Earth system models?, Geophysical Research Letters 41 (2014) 3535-3544.