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Earth System Dynamics Discussions

Interactive comment on "The exponential eigenmodes of the carbon-climate system" *by* M. R. Raupach

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General

This is a valuable paper making sense of a range of observations on the linear dynamic response of the global carbon cycle to anthropogenic forcing, building nicely on the Gloor et al., (2010) work. It is well researched and clearly written. Because of the short warning on the invitation to review this manuscript I'm afraid I haven't had time to check through things in as much detail as I'd liked, but all appears in order as far as I can tell. As a result I would recommend this paper is published once my minor points below are addressed.

Specific

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Interactive Discussion

Discussion Paper

Title: “The exponential eigenmodes of the carbon-climate system”. Is this the best title? For example, you also look at non-exponential inputs under mitigation.

P1108, L7... “is often approximated as a first-order linear system” should read “is often approximated as a number of a first-order linear systems” as it is rare that the GCC is treated as strictly first order. Indeed I remember Ian Enting taking me to task on this and I can think of only one published example of a strictly first order representation of the GCC.

P1110 L3... “Assumption Exp is historically approximately true for total CO2 emissions from fossil fuel combustion and net deforestation from 1750 to 2010”. Firstly, the observations only go back to 1850 (see Figure 1), so we don’t know what happened 1750-1849 (for fossil fuels at least). Secondly, I’m happy to be corrected but I think you need to credit Jarvis et al. (2012) NCC, 2, 668-671 for pointing out that total CO2 emissions are near exponential, as obvious as this might have appeared prior to then. Later you cite Peters et al., (2011) for this, but I have re-checked that reference and it makes no mention of this and definitely doesn’t demonstrate it as per Figure 1 in Jarvis et al. (2012) and now here also in Figure 1.

P1110 L18. “System” should read “system”.

P1113 L16...Perhaps an additional qualitative interpretation could be offered here to help the non-systems reader? One such could be that a first order dynamic system is a feedback process of the state on its own growth rate. When forced exponentially, the growth of this process is always dominated by the forcing input and not the feedback because the feedback always follows (is lagged) behind the forcing.

P1117 L20... “Figure 1 (upper panel) compares total CO2 emissions fE(t) with an exponential trajectory from 1850 to 2011, using an average growth rate of 1.89%yr$-$1 =(1/53) yr$-$1 (doubling time 36.7 yr).” Firstly this is a normalised growth rate or growth rate constant (the actual growth rate increases exponentially here). Secondly, I’m guessing you used OLS to estimate this normalised growth rate(?) because I get ex-

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actly this value using OLS with these data. However, as you mention later (but rather oddly in relation to an x,y regression), the regression residuals are highly autocorrelated (I get an AR(1) correlation of 0.9603). Unless you account for this when estimating your normalised growth rate the estimate will be asymtoptically biased. Accounting for the autocorrlation in the residuals I find gives 1.79% ($\pm$0.13) yr-1 (Jarvis et al., (2012)). Of course, this has very little impact on the following results but given you raise autocorrelation as an issue its important you address it. Finally, if you are right about the eigenmodes of the system then the normalised growth rate for the atmospheric burden should be the same as that of the total emissions. From memory I get a normalised growth rate of 53-1 yr-1 for atmospheric CO2 which is indistinguishable from the emissions normalised growth rate and possibly a more robust indicator than looking at the airborne fraction given its statistical properties should be better behaved(?).

P1119 L4. "CAF is a highly autocorrelated time series." See above. Also, if the author believes it is causing bias in his regression why not sort it out, especially when the estimates themselves are important for the story?

P1123 L26 "Using this clock" ?

P1125 L3 "1750" should read "1850" because this is talking about observed behaviour.

P1125 L18... "emissions will depart from present near-exponential growth (Peters et al., 2011)". As discussed above, I can't find any reference to exponential growth in total emissions in Peters et al., (2011) and definitely no proof of it using the observations.

P1126 L3... "One class of potential nonlinear effects that is of particular concern is the onset of threshold effects not yet evident in the carbon-climate system, typically associated with regional triggers that have global consequences." I appreciate why you are raising concerns over threshold nonlinearities here, but this is giving an imbalance to your thesis. The entire preceding paper demonstrates, using both observations and models, many linear and near linear traits of the system. To leave the reader with such a discordant nonlinear view is playing to the current climate science fashion of

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emphasising the importance of these nonlinearities relative to their linear counterparts. I suggest some balancing of arguments is required (both here and in the wider climate literature!).

P1126 L10... As discussed above, I'm afraid I haven't had time to go through this Appendix properly.

A. Jarvis – 27/09/12.

Interactive comment on Earth Syst. Dynam. Discuss., 3, 1107, 2012.