Earth Syst. Dynam. Discuss., 3, C646–C649, 2012
www.earth-syst-dynam-discuss.net/3/C646/2012/

Earth System Dynamics Discussions

ESDD

3, C646–C649, 2012

Interactive Comment

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

Anonymous Referee #2

Received and published: 14 November 2012

Overall: This is an important paper, putting on to a much more formal basis issues surrounding the observed constant airborne fraction. The paper should be accepted. My only overall criticism is that it might be nice to relate back much more to the process understanding, and in particular what might lie ahead that could break the "Lin" assumption. Obviously the "Exp" assumption is more related to socio-economic events, as captured in the RCP profiles.

Below are some suggestions below might be of use.

Title could be made more exciting and relevant - e.g. "Using exponential eigenmodes of carbon-climate system to test constancy of future airborne fraction". Without this the paper risks getting overlooked as more of a mathematical/technical paper.

Abstract - is it possible to get in here some process description of where the nonlinearities are? Is it mainly the ocean or land surface response?

Section 2.1. It is nice to see the mathematics written out. However there are some points where the description could be improved. For instance "The dimension of the state vector x(t) may be of order 10 for a simple, globally-aggregated model". A simple box model would be dimension unity?

Line 23. There is a chapter in "Avoiding Dangerous Climate Change", Chapter 15 which sets the conditions for runaway. Linearising around a (future) state might have negative lambdas.

The observation around Equation (7) that partition fraction and cumulative fraction asymptote to the same value deserves more prominence in the paper. If we believe the near-constant (instantaneous) airborne fraction is telling us information about cumulative emissions - and possibly in to the future - then this will identify more readily cumulative emissions to avoid two-degrees threshold for instance. (I guess extrapolation of Fig 4 for instance). I do realise the argument of this paper is that that would only be realised in the event of exponential emissions up to two-degrees followed by sudden cessation. i.e. "EXP" continues to a point where the world "panics" (e.g. unwelcome threshold) - then massive carbon capture and storage for instance is introduced.

Section 4.1. This is a part I would quite like to see expanded a bit. How nonlinear are predictions of future land and ocean storage? What are the current views on this? A missing paper that did trigger much debate over this sort of thing is Cox et al (2000), where the land surface is shown to potentially switch from sink to source. A more recent paper is Booth et al (2012) ERL, showing huge uncertainty in future terrestrial ecosystem sink, even when constrained to some extent by contemporary expert opinion on parameter bounds. Is there an equivalent ocean paper out there.

I really like the clarity of Section 4, sentence starting "This can happen for one or more of three reasons: ...failure of LIN......failure of EXP........effects of radiative forcing

ESDD

3, C646–C649, 2012

Interactive Comment

agents other than CO_2. I was then trying to relate this to the equations on page 16, V1-V5. There "Coupling" is listed as tested. Should therefore a 4th reason be "....changes to coupling strength"?

If it was of any use, one paper from UK researchers that highlights how non-CO_2 gases might trigger very different responses (for land surface storage and feedbacks at least) is "Highly contrasting effects of different climate forcing agents on terrestrial ecosystem services" Phil Trans R Soc A 2011, 369, 2026-2037.

OK, the thing that I would really like to see this paper stress much more is Figure 7 (a). With Q3000 the nearest to "business-as-usual", then this seems to suggest that despite nonlinearities in the climate system, then AF will remain near-constant for many decades. The paper states "..this is not because of the applicability of the LinExp idealisation, but instead because of compensating interactions between non-exponential emissions trajectories, nonlinear carbon-cycle dynamics and non-CO_2 gases". This is so important to characterise better, given at present there is little evidence of strong mitigation of emissions. Would it be possible to use the mathematics, or direct output from the model used, to show this as a stacked-histogram of the contributions to the blue curve of Figure 7. I can sort of see this information from Figure 8 (Fig 8: caption - please state scenario so can link to curve of Fig 7).

In other words, combine blue curve of Fig 7 with components of Fig 8, and also with a better wording in the paper. "These compensating effects correspond to a growing contribution due to EXP and a decaying contribution due to process X1, X2 in LIN". Have I got that correct? It feels all the answers are in the paper already, so it should need much work to get an improved plot and explanation.

In this balance of compensating terms, could at least some speculation be made as to when we might be able to pick apart the contributions in the measurement record. Obviously global CO_2 and T record are not sufficient as only give overall curves in Fig 7, but not the parts in Fig 8. This also relates to the very last paragraph of the paper

ESDD

3, C646–C649, 2012

Interactive Comment

"One class of potential nonlinear effects.....". Somehow this feels too important to be an almost throw away paragraph in the paper. How can society be alerted should this potentially very strong nonlinear feedbacks be switched on, thus breaking many model projects - including those in this paper.

Housekeeping things:

(a) Units please everywhere.

(b) Acronyms when written out - please capitalise

(c) If there is the opportunity, then it is a long paper - there may be places (e.g. Introduction) where things could be shortened.

(d) Typo - y-axis title of Figure 7b. CAF not FAC?

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