

Interactive comment on “What can be learned about carbon cycle climate feedbacks from CO₂ airborne fraction?” by M. Gloor et al.

Anonymous Referee #1

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I commend the authors for carefully writing up the obvious and thus busting the myth about the CO₂ airborne fraction (AF) that is being propagated by several famous names in the carbon cycle community. The myth is that the AF is a fundamental property of the system, rather than just an accident of how we force the system. The same myth applies to steady-state lifetimes, where much of the community thinks they are basic properties rather than merely diagnostics of the forcing. Well done. I recommend publication asap.

It is great to see this subject written up eruditely and cleanly. When I first read the IPCC AR4 WG1 Chapter 5 in prep for an undergraduate class, I was shocked and suspicious regarding the claim in the ES based on Table 5.1 that the change in AF was a demonstration that the ocean biogeochemistry was changing. This sounded false

and so I did a simple Bern CO₂ model with CDIAC FF-CO₂ to show that with fixed uptake, the AF changes with time (class lecture notes attached). Indeed the changes I calculated in the “Uptake fraction” had the same shift as they published. It was fun, and a good experience for the class. The distressing point was that this was a major recommendation of the chapter. Thus, I am pleased to see this ACP manuscript!

Some minor notes:

The paper seems long to say what needs to be said, and a bit tedious so that many may give up; but it is carefully written and so I have no obvious recommendations on how to shorten. The single e-fold model of the carbon cycle is less realistic, but it is simpler to explain, and the more complex one in the appendix shows that results from the single reservoir model scale.

The plot of the time scale of emissions (1e) is a bit meaningless, since it is the frequency that matters (/yr) and large timescales just mean it changed little from year to year. I would drop this one.

I really like the analytical solutions, but as the figures show, there is no constant growth rate in emissions (either FF or FF+LUCF). Thus Figure 2 is didactic to demonstrate the long time scale (similar to steady state in isotope numbers), but is not highly relevant to the current issue. It is very important to state clearly, as the authors do, that a steady-state AF cannot be achieved within any reasonable time frame (p. 9054).

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- Ocean biogeochemistry is changing. The total inorganic carbon content of the oceans has increased by 118 ± 19 GtC between the end of the pre-industrial period (about 1750) and 1994 and continues to increase. It is *more likely than not* that the fraction of emitted carbon dioxide that was taken up by the oceans has decreased, from $42 \pm 7\%$ during 1750 to 1994 to $37 \pm 7\%$ during 1980 to 2005. This would be consistent with the expected rate at which the oceans can absorb carbon, but the uncertainty in this estimate does not allow firm conclusions. The increase in total inorganic

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Table 5.1. Fraction of CO₂ emissions taken up by the ocean for different time periods.

Time Period	Oceanic Increase (GtC)	Net CO ₂ Emissions ^a (GtC)	Uptake Fraction (%)	Reference
1750–1994	116 ± 19	283 ± 19	42 ± 7	Sabine et al., 2004b
1980–2005 ^b	53 ± 9	143 ± 10	37 ± 7	Chapter 7 ^c

Notes:

- ^a Sum of emissions from fossil fuel burning, cement production, land use change and the terrestrial biosphere response.
^b The longest possible time period was used for the recent decades to minimise the effect of the variability in atmospheric CO₂.
^c Sum of the estimates for the 1980s, 1990s and 2000 to 2005 from Table 7.1.

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Fig. 1. IPCC class notes - p1

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<http://unfccc.int/resource/brazil/carbon.htm>

Parameters for tuning a simple carbon cycle model

Parties are free to use a more elaborate carbon cycle model if they choose.

CO₂ concentration approximation

The CO₂ concentration is approximated by a sum of exponentially decaying functions, one for each fraction of the additional concentrations, which should reflect the time scales of different sinks. The coefficients are based on the pulse response of the additional concentration of CO₂ taken from the Bern model (Siegenthaler and Joos, 1992).

$$p_{CO_2}(t) = C_{CO_2} \int_{-\infty}^t E_{CO_2}(t') \cdot \left[f_{CO_2,0} + \sum_{S=1}^n f_{CO_2,S} \cdot e^{\left(\frac{-t-t'}{\tau_{CO_2,S}}\right)} \right] dt'$$

r = concentration

C_{CO_2} = constant (approximately 0.47 ppmv/GtC, but use this parameter to fine tune your results)

E_{CO_2} = emissions of CO₂

$\tau_{CO_2,S}$ = atmospheric exponential decay time of the s^{th} fraction of the additional concentration (171.0, 18.0 and 2.57 years)

$f_{CO_2,0}$ = first fraction (0.152)

$f_{CO_2,S}$ = respective fractions (0.253, 0.279 and 0.316)

Fig. 2. IPCC class notes - p2

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c---test of fraction of CO2 uptake          7 May 2007
implicit none
real A0,A1,A2,A3,T1,T2,T3
real E(2100),SUMC,SUMA
integer I,II,J1,J2

c---Bern TAR model for CO2 uptake by land+ocean (Joos et al.)
data A0,A1,A2,A3 /0.152, 0.253, 0.279, 0.316/
data T1,T2,T3 / 171.0, 18.0, 2.57/

do II=1,2100
  E(II) = 0.0
enddo

c--CDIAC anthropogenic CO2 emisissions (fossil fuel and cement), no LUCF
open (1, file='CO2-global-1751_2003.csv', status = 'OLD')

read(1,*)
do II=1,2100
  read (1,*,end=2) I,E(I)
enddo
2 continue

do II=1,2100
  E(II) = 0.001*E(II)
enddo

3 continue
read(5,*,end=4) J1,J2
SUMC = 0.0
SUMA = 0.0
do I = J1,J2
  SUMC = SUMC + E(I)
  SUMA = SUMA + E(I)* (A0 + A1*exp((I-J2)/T1) + A2*exp((I-J2)/T2)
& + A3*exp((I-J2)/T3) )
enddo

write (6,'(2i5,2f10.3,f10.4)') J1,J2, SUMC,SUMA, SUMA/SUMC
goto 3

4 continue
stop
end

```

C	-----	%uptake	
C	1980 2005 161.314 95.354 0.5911 41%		37 ± 7
C	1750 1994 244.547 119.635 0.4892 51%		42 ± 7
C	1750 2005 320.163 152.810 0.4773 52%		

Fig. 3. IPCC class notes - p3

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