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Comment

Comment on "Ocean heat content and Earth's radiation imbalance. II. Relation to climate shifts"

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ABSTRACT

A recent paper by Douglass and Knox (hereafter DK12) states that the global flux imbalance between 2002 and 2008 was approximately -0.03 ± 0.06 W/m^2, from which they concluded the CO_2 forcing feedback is negative. However, DK12 only consider the ocean heat content (OHC) increase from 0 to 700 meters, neglecting the OHC increase at greater depths. Here we include OHC data to a depth of 2000 meters and demonstrate this data explains the majority of the discrepancies between DK12 and previous works, and that the current global flux imbalance is consistent with continued anthropogenic climate change.

1. Introduction

The global energy imbalance, the difference between energy entering and leaving Earth's atmosphere, is an important global warming metric because it indicates the amount of unrealized warming in the climate system [1]. Reconciling changes in radiation flux at the top-of-the-atmosphere (TOA) with heat fluxes on Earth remains a challenge, in large part due to sparse measurements of deep ocean heat content (OHC) [2]. Recent research has determined that all radiative forcings [3] and heat content of the entire ocean, at all depths must be considered to reconcile these two quantities [4], including the upper 2000 meters of oceans in particular [5].

DK12 [6] conclude that the global flux imbalance between 2002 and 2008 was -0.03 ± 0.06 Watts per square meter (W/m^2); however, the authors only considered the OHC of the upper 700 meter ocean layer. Neglecting the deeper oceans and other global heating (such as of the land, atmosphere, and ice [LAI]) results in significantly underestimating the global heat flux (see Section 3). Additionally, in concluding that the carbon dioxide (CO_2) forcing feedback is negative, DK12 fail to consider significant impacts on the earth's energy imbalance from other significant radiative forcings such as anthropogenic and volcanic aerosols [3,7–9]. DK12 also fail to estimate the impact of analyzing different time periods on their conclusion regarding the CO_2 forcing feedback. For example, for the period of 1991 to 2002, DK12 find a flux imbalance of 0.33 ± 0.06 W/m^2, which is of similar magnitude to the net radiative forcing during that timeframe [10], and thus is inconsistent with their conclusion of a net negative feedback. DK12 justify their conclusion by claiming that the climate underwent a 'climate shift' from 2002 to 2008. However, including heating of the oceans from 700 to 2000 meters and LAI nullifies the DK12 conclusion even during the 2002–2008 timeframe. Moreover, in focusing exclusively on short-term interannual and decadal changes, DK12 neglect long-term multidecadal climate changes.

2. Data and methods

As in DK12, the principal OHC data set used in this study is an update [11] of that of Levitus et al. (2009) [12], Levitus et al. (2012) [13]. However, contrary to the OHC data used in DK12, this study uses data to a depth of 2000 meters rather than 700 meters, representing a significant increase in overall ocean coverage. This new dataset consists of a five-year (pentadal) average of OHC measured to a depth of 2000 meters and summed over the world's oceans, from 1960 through the 2007–2011 period. Changes and improvements to the basic data since 2009 are summarized in DK12. LAI heating data used in this study originate from Church et al. (2011) [3].

All data are expressed in units of 10^{22} Joules. To relate OHC to radiative imbalance, similar to DK12, we use

$$F_{TOA} = 0.62\left[d(\mathrm{OHC})/dt\right] \quad (1)$$

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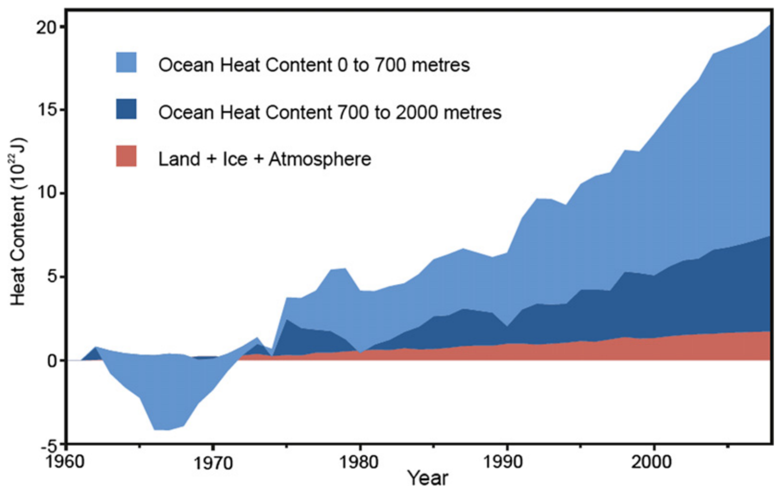

Fig. 1. Land, atmosphere, and ice heating (red), 0–700 meter OHC increase (light blue), 700–2000 meter OHC increase (dark blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this Letter.)

Table 1
Global flux imbalance during selected periods.

Time period	0–700 meter OHC (W/m^2)	700–2000 meter OHC (W/m^2)	LAI heating (W/m^2)	Net heat content increase (W/m^2)
1970–2008	0.21 ± 0.063	0.082 ± 0.030	0.025 ± 0.0012	0.31 ± 0.078
1980–2008	0.23 ± 0.062	0.12 ± 0.017	0.027 ± 0.0019	0.37 ± 0.068
1990–2008	0.29 ± 0.082	0.14 ± 0.11	0.030 ± 0.0031	0.46 ± 0.063
2000–2008	0.35 ± 0.13	0.15 ± 0.020	0.029 ± 0.0068	0.53 ± 0.11
2002–2008	0.44 ± 0.17	0.26 ± 0.039	0.036 ± 0.0044	0.73 ± 0.16

where F_{TOA} is the radiative imbalance at the top-of-the-atmosphere (inward) in units of W/m^2, and time is in years. The factor 0.62 is a result of converting 10^{22} J/year to Watts and dividing by Earth's area to obtain the flux. In their calculation, DK12 also included a term associated with the Earth's geothermal flux; however, we have omitted this term because the geothermal flux is relatively constant, whereas this analysis focuses on recent perturbations.

3. Results

Fig. 1 shows the pentadal OHC data for the 0–700 meter layer [11] (the only data considered by DK12), the 700–2000 meter layer [11], and LAI heating from 1961 to 2008 [3].

Contrary to the results of DK12, there is no significant decrease or flattening in total heat content during the past decade, as illustrated in Table 1, similar to results in Church et al. [3]. We find that the OHC increase for the 700–2000 meter layer neglected by DK12 accounts for approximately 30% of the 0–2000 meter increase in recent decades.

Our 0–700 meter result differs from that of DK12 over the 2002–2008 period because we use pentadal data whereas DK12 use quarterly data. This result highlights the fact that the DK12 conclusions are a result of their focus on short-term noise

Additionally, in their analysis DK12 only account for CO_2 and solar radiative forcing while ignoring the total sum of radiative forcings impacting OHC. However, Solomon et al. (2011) recently conclude that an increase in atmospheric aerosols between 2000 and 2010 caused a -0.1 W/m^2 radiative forcing [7], offsetting approximately 35% of the CO_2 forcing and 30% of the net greenhouse gas forcing during that period; DK12 did not account for this aerosol forcing. Moreover, Vernier et al. (2011) find a major influence of moderate strength tropical volcanic eruptions on the stratospheric aerosol layer over the last decade [8]. DK12 also excluded the forcing from non-CO_2 greenhouse gases in their analysis. The radiative forcing considered by DK12 is compared to the total net radiative forcing in Hansen et al. (2011) [9] in Fig. 2.

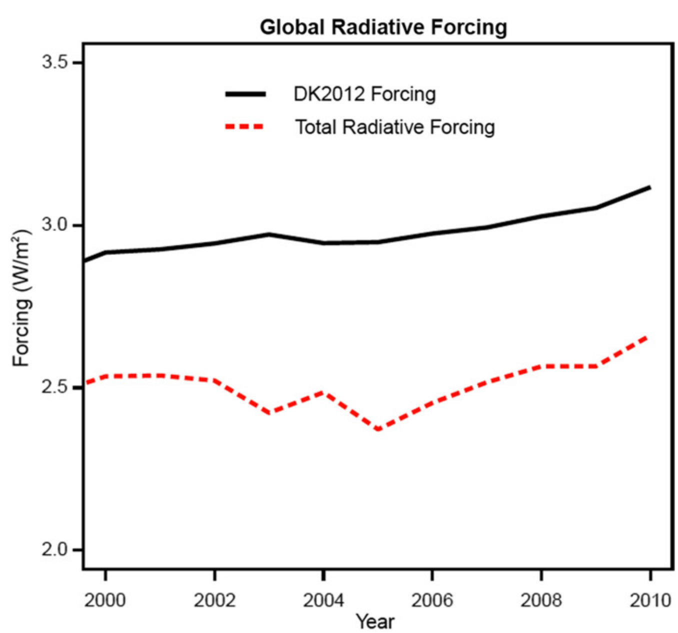

Fig. 2. Comparison of selective radiative forcing used by DK12 (black) and total radiative forcing used by Hansen et al. (2011) (red) over the period 2000 to 2010. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this Letter.)

4. Discussion

DK12 noted that their results were inconsistent with a number of other studies: Lyman et al. [14], von Schuckmann and Le Traon [15], Loeb et al. [5], Hansen et al. [9], whose heat content increase estimates for recent years range from ∼0.37 to ∼0.63 W/m^2. They are also inconsistent with the results of Church et al. [3]. However, when including the 700–2000 meter OHC and LAI heating data, our results are consistent with these previous studies. These deeper ocean data account for approximately 30% of the net global heating in recent decades, and thus must be taken into account in any evaluation of global heat flux.

A key conclusion in DK12, that the net CO_2 feedback is negative, is also based exclusively on an analysis of data during one of their proposed 'climate shift' periods (2002–2008) with a negative flux imbalance. However, this conclusion does not hold during the 'climate shift' periods with a larger positive flux imbalance, and thus the conclusion is not robust. Additionally, accounting for the heating of the oceans from 700 to 2000 meters and LAI nullifies the DK12 conclusion even during the 2002–2008 timeframe. The CO_2 feedback is effectively a constant value, and thus should not be calculated using such a short timeframe when data over a longer period are available. The DK12 feedback calculation is invalidated by focusing on noisy short-term data and failing to account for all radiative forcings at work, as well as all heat reservoirs, in particular the oceans below 700 meters.

The DK12 analysis suffered from only considering a portion of the global heat content increase (0–700 meter OHC), and only during the interannual and decadal timeframes of their proposed 'climate shifts.' However, focusing on short timeframes results in larger data uncertainty than analysis of multidecadal trends (as illustrated in Table 1); hence long-term trends may be difficult to discern, particularly when a significant portion of the data (i.e. 700–2000 meter OHC) are neglected.

The DK12 conclusion regarding the CO_2 feedback also failed to consider all radiative forcings other than those associated with solar irradiance and CO_2, most notably volcanic and anthropogenic aerosol emissions, and non-CO_2 greenhouse gases.

Finally, DK12 estimated an 87% decrease in OHC trends in 2002–2008 as compared to 1991–2002. However, this is difficult to reconcile with the global mean sea level (GMSL) record over their period of analysis. We would expect any reduction or stagnation of OHC in recent years to be accompanied by a corresponding flattening/reduction in GMSL rise due to reduced thermal expansion of the oceans. On the contrary, the rate of GMSL rise was statistically indistinguishable during the proposed 2002–2008 'climate shift' (2.85 ± 0.46 mm/year) and the 1991–2002 'climate shift' (2.78 ± 0.50 mm/year), and was overall higher than the 1961–2008 average GMSL rise (1.95 ± 0.24 mm/year) [3].

To account for the difference between the expected decline in the thermal expansion contribution to GMSL based on DK12 results and observed continued GMSL rise, ice sheets, glaciers, and ice caps would have to be contributing significantly more of the observed sea level rise than current best estimates suggest (1.48 ± 0.26 mm/year) [16], implying either error in DK12's analysis or that cryospheric contributions have accelerated considerably, raising the possibility that future sea level rise may be greater than currently projected.

Overall, when considering OHC data to a depth of 2000 meters, as well as land, atmosphere, and ice heating, our results are consistent with the previous studies referenced above, most of which consider OHC to 2000 meters. We find no evidence that the global flux imbalance has declined significantly in recent years, or that the CO_2 feedback is negative or inconsistent with climate models.

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References

[1] J. Hansen, L. Nazarenko, R. Ruedy, M. Sato, J. Willis, A. Del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakov, J. Perlwitz, G. Russell, G.A. Schmidt, N. Tausnev, Science 308 (2005) 1431, http://dx.doi.org/10.1126/science.1110252.
[2] K.E. Trenberth, Current Opinion on Environmental Sustainability 1 (2009) 19, http://dx.doi.org/10.1016/j.cosust.2009.06.001.
[3] J.A. Church, N.J. White, L.F. Konikow, C.M. Domingues, J.G. Cogley, E. Rignot, J.M. Gregory, M.R. van den Broeke, A.J. Monaghan, I. Velicogna, Geophysical Research Letters 38 (2011) L18601, http://dx.doi.org/10.1029/2011GL048794.
[4] M.D. Palmer, D.J. McNeall, N.J. Dunstone, Geophysical Research Letters 38 (2011) L13707, http://dx.doi.org/10.1029/2011GL047835.
[5] N.G. Loeb, J.M. Lyman, G.C. Johnson, R.P. Allan, D.R. Doelling, T. Wong, B.J. Soden, G.L. Stephens, Nature Geoscience 5 (2012) 110, http://dx.doi.org/10.1038/ngeo1375.
[6] D.H. Douglass, R.S. Knox, Physics Letters A 376 (14) (2012) 1226, http://dx.doi.org/10.1016/j.physleta.2012.02.027.
[7] S. Solomon, J.S. Daniel, R.R. Neely, J.P. Vernier, E.G. Dutton, L.W. Thomason, Science 333 (2011) 866, http://dx.doi.org/10.1126/science.1206027.
[8] J.-P. Vernier, L.W. Thomason, J.-P. Pommereau, A. Bourassa, J. Pelon, A. Garnier, A. Hauchecorne, L. Blanot, C. Trepte, D. Degenstein, F. Vargas, Geophysical Research Letters 38 (2011) L12807, http://dx.doi.org/10.1029/2011GL047563.
[9] J. Hansen, M. Sato, P. Kharecha, K. von Schuckmann, Atmospheric Chemistry and Physics Discussion 11 (2011) 27031, http://dx.doi.org/10.5194/acpd-11-27031-2011.
[10] R.B. Skeie, T.K. Berntsen, G. Myhre, K. Tanaka, M.M. Kvalevåg, C.R. Hoyle, Atmospheric Chemistry and Physics Discussion 11 (2011) 22545, http://dx.doi.org/10.5194/acpd-11-22545-2011.
[11] NOAA/NODC, Data at ftp://ftp.nodc.noaa.gov/pub/data.nodc/woa/data_analysis_heat_content/data/basin, 2012.
[12] S. Levitus, J. Antonov, T. Boyer, R. Locarini, H. Garcia, A. Mishonov, Geophysical Research Letters 36 (2009) L07608, http://dx.doi.org/10.1029/208GL037155.
[13] S. Levitus, et al., Geophysical Research Letters 39 (2012) L10603, http://dx.doi.org/10.1029/2012GL051106.
[14] J.M. Lyman, et al., Nature 465 (2010) 334, http://dx.doi.org/10.1038/nature09043.
[15] K. von Schuckmann, P. Le Traon, Ocean Science Discussion 8 (2011) 999, http://dx.doi.org/10.5194/osd-8-999-2011.
[16] T. Jacob, J. Wahr, W. Pfeffer, S. Swenson, Nature 482 (2012) 514, http://dx.doi.org/10.1038/nature10847.