A fast method for updating global fossil fuel carbon dioxide emissions

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Abstract

We provide a fast and efficient method for calculating global annual mean carbon dioxide emissions from the combustion of fossil fuels by combining data from an established data set with BP annual statistics. Using this method it is possible to retrieve an updated estimate of global CO2 emissions six months after the actual emissions occurred. Using this data set we find that atmospheric carbon dioxide emissions have increased by over 40% from 1990 to 2008 with an annual average increase of 3.7% over the five-year period 2003–2007. In 2008 the growth rate in the fossil fuel carbon dioxide emissions was smaller than in the preceding five years, but it was still over 2%. Global mean carbon dioxide emissions in 2008 were 8.8 GtC yr−1. For the latter part of the last century emissions of carbon dioxide have been greater from oil than from coal. However during the last few years this situation has changed. The recent strong increase in fossil fuel CO2 emissions is mainly driven by an increase in emissions from coal, whereas emissions from oil and gas to a large degree follow the trend from the 1990s.

Keywords: fossil fuel CO2 emissions, IPCC scenarios

1. Introduction

CO2 is the main driver of human induced climate change and will be the key component of future climate change (Hansen et al. 2007, IPCC 2007). Atmospheric CO2 concentrations have increased from 280 ppm in 1750 to 383 ppm in 2007, with a recent trend of about 2 ppm yr−1 (WMO 2008). Approximately 75% of this increase is due to CO2 emissions from fossil fuel combustion while the remaining 25% is due to increased emissions from land use (IPCC 2007). Whereas the trend in CO2 emissions from land use over the last few decades has been relatively constant, an increasing trend in fossil fuel CO2 emissions has been reported (Canadell et al. 2007, Forster et al. 2007, Raupach et al. 2007). This increasing trend is driven by enhanced economic growth and also an increase in carbon intensity (Canadell et al. 2007). In addition, atmospheric CO2 concentrations may be affected by a small increase in the atmospheric airborne fraction of CO2 recently reported by Canadell et al. 2007 and Raupach et al. 2008). A weakening of the oceanic CO2 sink has been noted (Le Quere et al. 2007). All main IPCC scenarios of fossil fuel CO2 emissions show an increase over the next few decades with a large spread in emissions estimates up to 2100. Raupach et al (2007) suggest that current fossil fuel CO2 emissions are even higher than all CO2 emission SRES scenarios. Future atmospheric CO2 concentrations not only depend on the emissions, but also on the net uptake of CO2 by land and ocean (Friedlingstein et al. 2006).

Data on fossil fuel CO2 emissions from 1751 to 2006 are held at the Carbon Dioxide Information Analysis Center (CDIAC; http://cdiac.ornl.gov/) (Andres et al. 1999, Gregg et al. 2008). The data are updated regularly so they yield information about emissions released two to three years behind real time. The energy company BP (http://bp.com) provides annual statistics of fossil fuel consumption, treating gas, oil and coal separately. This data set is updated every year and only lags six months behind real time. In this study we provide a method for combining these two data sets to update fossil fuel CO2 emissions. This provides a method with a shorter time lag for estimating global fossil fuel CO2 emissions and thus allows an earlier comparison with scenarios of fossil fuel CO2 emissions.
2. Method

The fossil fuel CO₂ emission \( E(\text{CO}_2) \) for one particular year can be calculated according to equation (1) below.

\[
E(\text{CO}_2)_{\text{year}} = \sum_i \frac{C(\text{OIL})(\text{BP})_{i,\text{year}}}{C(\text{OIL})(\text{BP})_{\text{Ref-year}}} \times E(\text{CO}_2)(\text{CDIAC})_{i,\text{Ref-year}}
\]

where \( C(\text{OIL})(\text{BP})_{i,\text{year}} \) is the global oil equivalent consumption according to BP for a fossil fuel type \( i \) for a particular year and \( E(\text{CO}_2)(\text{CDIAC})_{i,\text{Ref-year}} \) is the fossil fuel CO₂ emission for type \( i \) from CDIAC for a reference year. Raupach et al. (2007) divided the fossil fuel emissions into seven sources, and solid, liquid, and gas contribute more than 90% of the total fossil fuel emissions. We add fossil fuel sources other than solid, liquid, and gas from CDIAC to the BP data set and for 2007 and 2008 the growth rate is assumed to be the same as the mean of the increase between 2004 and 2006.

3. Results

A new fossil fuel CO₂ emissions data set, \( E(\text{CO}_2) \), has been created using equation (1) with CDIAC data as a reference value for 1990 and BP data to calculate for consecutive years. Figure 1 shows close agreement between this new data set, herein referred to as the BP data, and CDIAC data over the period from 1990 to 2006. The difference between CDIAC data and the method applied to the results from the BP data is less than 2.5%. The figure shows an almost uniform increase in fossil fuel CO₂ emissions and a greater increase after 2000 than between 1990 and 2000 as shown earlier (Raupach et al. 2007). The BP data show a continued large growth in the CO₂ emissions for 2007 and 2008, but slightly weaker growth than some of the previous years. Fossil fuel emissions of CO₂ in 2008 were around 8.8 GtC yr⁻¹, which is an increase of more than 40% since 1990. The strongest annual increase was in year 2004 and was about 5%. For the years 2003–2007 the increase was above 3%, whereas between 1990 and 2002 the increase was generally lower. Despite the financial downturn that started in the latter part of 2008, fossil fuel emissions still increased in 2008 but by 2.2% for the year which is less than for the preceding five-year period.

Figure 1 also shows the main IPCC SRES scenarios (IPCC 2001). In Raupach et al. (2007) a slightly different approach was used with means of groups of scenarios. Unlike Raupach et al. (2007) we show in figure 1 that one of the scenarios (A1B) has higher estimates of fossil fuel emissions of CO₂ than the observed emissions. This scenario predicts higher emissions than the actual emissions and has a peak in the emissions of about 16 GtC yr⁻¹ in 2050 and around 13 GtC yr⁻¹ in 2100. However, the actual emissions are higher than the rest of the SRES scenarios, among them scenarios with fossil fuel CO₂ emissions of around 30 GtC yr⁻¹ in 2100. The emissions in 2008 are at the same level as the median of the IPCC scenarios about five years later. Figure 1(c) shows that the growth rate of the fossil fuel CO₂ emissions between 2003 and 2007 is overall higher than A1B, but weaker during the last few years. It is also clear that, although the growth rate was similar to the IPCC scenarios (except A1B) between 2000 and 2002, the growth rate between 2003 and 2007 was substantially larger than the predictions in the IPCC scenarios. Although the growth rate in 2008 was weaker than those for the five previous years, it is higher than all IPCC scenarios with the exception of A1FI and A1B.
Figure 2. Fossil fuel CO$_2$ emissions from gas, oil, and coal derived from BP data in the period 1990–2008 and similar data from CDIAC in the period 1990–2006. For the CDIAC data, fossil fuel CO$_2$ emissions from sources other than gas, oil, and coal are included. After 2006 the same annual growth as the mean between 2004 and 2006 has been applied to sources for fossil fuel CO$_2$ other than gas, oil, and coal.

Figure 2 shows the CO$_2$ emissions for each of the different fuel types. Again the agreement between the CDIAC data and BP data is good, and particularly for oil and gas. Despite the fact that emissions from oil have flattened out over the last few years and even decreased in 2008, CO$_2$ emissions from gas and oil have increased quite linearly over the period 1990 to 2008. On the other hand emissions from coal were rather stable between 1990 and 2000, with a strong increase after 2000. Fossil fuel CO$_2$ emissions from coal have increased more than 35% over the last six years, driving most of the strong increase in fossil fuel CO$_2$ emissions. Over the period 1990–2008 the increases in CO$_2$ emissions have been around 25%, 48%, and 54% for oil, coal, and gas, respectively.

Figure 2 also shows that CO$_2$ emissions from coal were higher than from oil after 2005, whereas CO$_2$ emissions from oil were higher for the 20 years prior to that. CO$_2$ emissions from oil were also larger than from coal in the 1970s and early 1980s. In 2008 the coal CO$_2$ emissions are more than 12% higher than the oil CO$_2$ emissions, which are about twice as large as the difference between the data based on CDIAC and BP. In 2008 the difference between the fossil fuel emissions from coal and oil continues to increase, with a slight reduction in the emissions from oil and a continued increase in the emissions from coal.

Fossil fuel CO$_2$ emissions are divided into eight regions in figure 3. Separate emissions for USA, Japan, Former Soviet Union (FSU), China, and India are given in the figure. The EU countries are grouped together and D1 represents developed countries except those given separately for EU, Japan, and USA. D2 and D3 are the developing and least developed countries respectively and a further description is given in Raupach et al (2007). We have grouped the D2 and D3 countries together since the CO$_2$ emissions from D3 are very small (Raupach et al 2007). All eight regions have increased fossil fuel CO$_2$ emissions from 1990 to 2008, except FSU and EU. In the FSU the reduction over this time period is more than 35%, whereas there has been a modest reduction of 4% in the EU. For the group of countries in the FSU, reductions in the fossil fuel CO$_2$ emissions occurred in the 1990s followed by an increase for all years after 2000 (except 2007). The increases in USA and Japan are 17% and 12%, respectively, whereas the global increase is 18%.

In China and India, fossil fuel CO$_2$ emissions have more than...
doubled, with the largest increase in China (emissions higher by almost a factor of three). The percentage contribution to the CO$_2$ emissions was 11% of the total for China in 1990 and has doubled to 22% in 2008. Likewise, the percentage contribution of the total fossil fuel CO$_2$ emission has doubled from 3% in 1990 to 6% in 2008 for India. In agreement with an earlier study (Gregg et al 2008) we also find that China is now the largest fossil fuel CO$_2$ emitter on a country basis. A main reason for the strong increase in the fossil fuel emissions from China is due to production and export to other countries (Guan et al 2009). The contributions to the total global mean fossil fuel CO$_2$ emissions from other regions have mostly decreased due to the large increase in China and India, e.g. in the USA the contribution has decreased from 22% in 1990 to 18% in 2008. In 1990 the contribution of the total fossil fuel CO$_2$ emission from China, India, D2, and D3 was close to 1/3 but in 2008 it had risen to more than half of the emissions. The percentage growth of CO$_2$ emissions has been above 5% since 2002 and over 15% in China in years 2003 and 2004 (figure 3(c)). Since 2000 the changes in the USA and EU emissions have been relatively small. USA had the strongest reduction in fossil fuel CO$_2$ emissions in 2008. For the two last years India has had the strongest growth in the CO$_2$ emissions, closely followed by China.

4. Summary

By combining two different data sets we are able to update the global and annual fossil fuel emissions of CO$_2$ to within six months of the present. Fossil fuel CO$_2$ emissions have been increasing strongly over the last six years, mainly due to a large increase in the use of coal that has taken place in China. Although this increase in CO$_2$ emissions is attributed to China, a large share of the growth is due to export and consumption in other countries (Guan et al 2009). In 2008 global fossil fuel CO$_2$ emissions were 8.8 GtC yr$^{-1}$ and this is higher than all main IPCC 2007 scenarios, except one. Since 2006 the CO$_2$ emissions from coal were higher than from oil, thus reversing the dominance of global CO$_2$ emissions from oil over the last two decades. This trend also continues in 2008 with a slight reduction in the fossil fuel CO$_2$ emissions from oil and a significant increase in the CO$_2$ emissions from coal. The overall trend for 2008 is an estimated increase of 2.2% in the fossil fuel CO$_2$ emissions despite the onset of the global financial depression in that year.

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