Carbon Budget 2009
GCP-Carbon Budget2009 Contributors

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http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo1022.html
Units

- 1 Pg = 1 Petagram = $1 \times 10^{15}$ g = 1 Billion metric tons = 1 Gigaton
- 1 Tg = 1 Teragram = $1 \times 10^{12}$ g = 1 Million metric tons
- 1 Kg Carbon (C) = 3.67 Kg Carbon Dioxide (CO$_2$)
Fossil Fuel CO$_2$ Emissions

Emissions: $8.4 \pm 0.5$ PgC

- Growth rate: $-1.3\%$ 1990 level: $+37\%$
- 2000-2008: Growth rate: $+3.2\%$
- 2010 (projected): Growth rate: $>3\%$

CO$_2$ emissions (Pg C y$^{-1}$)

Growth rate 2000-2009: 2.5 % per year

Growth rate 1990-1999: 1 % per year

Time (y)
Fossil Fuel CO$_2$ Emissions: Top Emitters

Carbon Emissions per year (C tons x 1,000,000)

Time (y)

China
USA
India
Russian Fed.
Japan

Global Carbon Project 2010; Data: Gregg Marland, Tom Boden-CDIAC 2010
Fossil Fuel CO$_2$ Emissions

Updated from Le Quéré et al. 2009, Nature Geoscience; CDIAC 2010
Top 20 CO₂ Emitters & Per Capita Emissions 2009

Global Carbon Project 2010; Data: Gregg Marland, Thomas Boden-CDIAC 2010; Population World Bank 2010
CO₂ Emissions by Fossil Fuel Type

Updated from Le Quéré et al. 2009, Nature Geoscience; Data: Gregg Marland, Thomas Boden-CDIAC 2010

CO₂ emissions (PgC y⁻¹)

- Oil
- Coal
- Gas
- Cement

Time (y)

1990 2000 2010

36% 40%

CO₂ emissions (PgC y⁻¹)
Change in CO$_2$ Emissions from Coal (2007 to 2009)

92% of growth

Global Carbon Project 2010; Data: Gregg Marland, Thomas Boden-CDIAC 2010
Fossil Fuel Emissions: Actual vs. IPCC Scenarios

Updated from Raupach et al. 2007, PNAS; Data: Gregg Marland, Thomas Boden-CDIAC 2010; International Monetary Fund 2010
Fluxes of Emissions Embodied in Trade (Mt CO$_2$ y$^{-1}$)

From dominant net exporting countries (blue) to dominant net importing countries (red).

Davis & Caldeira 2010, PNAS; See also Peters & Hertwich 2008, Environ, Sci & Tech.
**CO₂ Emissions from FF and LUC (1960-2009)**

CO₂ emissions (PgC y⁻¹)

- **Fossil fuel**
- **Land use change**

LUC emissions now ~10% of total CO₂ emissions

Updated from Le Quéré et al. 2009, Nature Geoscience
CO₂ Emissions from Land Use Change

1990s
Emissions: 1.5±0.7 PgC

2000-2005
Emissions: 1.3±0.7 PgC

2006-2010:
Emissions: 0.9±0.7 PgC

Friedlingstein et al. 2010, Nature Geoscience; Data: RA Houghton, GFRA 2010
Emissions from Land Use Change (1850-2009)

CO₂ emissions (TgC y⁻¹)

-400 -200 0 200 400 600 800 1000 1200 1400 1600 1800

Time (y)


Tropical
Temperate

R.A. Houghton 2010, personal communication; GFRA 2010
Emissions from Land Use Change (1850-2009)

- 200
- 0
- 200
- 400
- 600
- 800
- 1000

- 1850
- 1860
- 1870
- 1880
- 1890
- 1900
- 1910
- 1920
- 1930
- 1940
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010

Latin America
S & SE Asia
Tropical Africa

CO₂ emissions (Tg C y⁻¹)

Time (y)
Fire Emissions from Deforestation Zones

Global Fire Emissions Database (GFED) version 3.1

Time (y)

Fire Emissions from deforestation zones (Tg C y⁻¹)

- America
- Africa
- Asia
- Pan-tropics

van der Werf et al. 2010, Atmospheric Chemistry and Physics Discussions
Atmospheric CO$_2$ Concentration

Data Source: Pieter Tans and Thomas Conway, 2010, NOAA/ESRL

- 1970 – 1979: 1.3 ppm y$^{-1}$
- 1980 – 1989: 1.6 ppm y$^{-1}$
- 1990 – 1999: 1.5 ppm y$^{-1}$
- 2000 – 2009: 1.9 ppm y$^{-1}$

Annual Mean Growth Rate (ppm y$^{-1}$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth Rate (ppm y$^{-1}$)</th>
</tr>
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<tbody>
<tr>
<td>2009</td>
<td>1.62</td>
</tr>
<tr>
<td>2008</td>
<td>1.80</td>
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<tr>
<td>2007</td>
<td>2.14</td>
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<tr>
<td>2006</td>
<td>1.84</td>
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<td>2005</td>
<td>2.39</td>
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<td>2004</td>
<td>1.60</td>
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<td>2002</td>
<td>2.40</td>
</tr>
<tr>
<td>2001</td>
<td>1.89</td>
</tr>
<tr>
<td>2000</td>
<td>1.22</td>
</tr>
</tbody>
</table>

December 2009: 387.2 ppm
September 2010 (preliminary): 389.2 ppm
39% above pre-industrial

GLOBAL MONTHLY MEAN CO$_2$

- November 2010
  - Parts Per Million (ppm): 390
- Parts Per Million (ppm): 388
- Parts Per Million (ppm): 386
- Parts Per Million (ppm): 384
- Parts Per Million (ppm): 382
- Parts Per Million (ppm): 380
- Parts Per Million (ppm): 378

Global Carbon Project
Key Diagnostic of the Carbon Cycle

Evolution of the fraction of total emissions that remain in the atmosphere

Updated from Le Quéré et al. 2009, Nature Geoscience; Data: NOAA 2010, CDIAC 2010

CO₂ Partitioning (PgC·y⁻¹)

Time (y)

Total CO₂ emissions

Atmosphere
Airborne Fraction

Fraction of total CO₂ emissions that remains in the atmosphere

Trend: 0.31 % y⁻¹ (p≈0.9)

Updated from Le Quéré et al. 2009, Nature Geoscience; Raupach et al. 2008, Biogeosciences; Canadell et al. 2007, PNAS
Modelled Natural CO$_2$ Sinks

- Land sink (PgCy$^{-1}$): 5 models
- Ocean sink (PgCy$^{-1}$): 5 models

Time (y): 1960 to 2010

Updated from Le Quéré et al. 2009, Nature Geoscience
Human Perturbation of the Global Carbon Budget

\[ \text{CO}_2 \text{ flux (PgC y}^{-1}) \]

- Source: deforestation

- Sink: 1.1 ± 0.7

Time (y)

- 1850
- 1900
- 1950
- 2000

2000-2009 (PgC)

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS
Human Perturbation of the Global Carbon Budget

CO$_2$ flux (PgC y$^{-1}$)

Source

Sink

fossil fuel emissions

deforestation

1850 1900 1950 2000

Time (y)

2000-2009 (PgC)

7.7±0.5

1.1±0.7

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS
Human Perturbation of the Global Carbon Budget

- Time (y)
  - 1850
  - 1900
  - 1950
  - 2000

- Sink
  - CO$_2$ flux (PgC y$^{-1}$)
  - 2000-2009
  - 7.7±0.5
  - 1.1±0.7

- Source
  - fossil fuel emissions
  - deforestation

Source: Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS
Human Perturbation of the Global Carbon Budget

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

CO$_2$ flux (PgC y$^{-1}$)

fossil fuel emissions

deforestation

atmospheric CO$_2$

Time (y)

Sink

Source

2000-2009 (PgC)

7.7±0.5

1.1±0.7

4.1±0.1

1850 1900 1950 2000
Human Perturbation of the Global Carbon Budget

![Graph showing carbon fluxes over time](image)

- **Fossil fuel emissions**
- **Deforestation**
- **Atmospheric CO\(_2\)**
- **Ocean**

**Time (y)**

- **1850**
- **1900**
- **1950**
- **2000**

**CO\(_2\) flux (PgC y\(^{-1}\))**

- **Sink**
- **Source**

- **2000-2009**

- **7.7 ± 0.5** (PgC)
- **1.1 ± 0.7**
- **4.1 ± 0.1**
- **2.3 ± 0.4** (5 models)

**Notes:**
- Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

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Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS
Human Perturbation of the Global Carbon Budget

![Graph showing CO₂ fluxes over time]

- **fossil fuel emissions**
- **deforestation**
- **atmospheric CO₂**
- **land**
- **ocean**

**1850 to 2000**

- **CO₂ flux (PgC y⁻¹)**
  - **2000-2009**
    - **7.7 ± 0.5**
    - **1.1 ± 0.7**
    - **4.1 ± 0.1**
    - **2.4 (Residual)**
    - **2.3 ± 0.4** (5 models)

**Time (y)**
Fate of Anthropogenic CO$_2$ Emissions (2000-2009)

1.1±0.7 PgC y$^{-1}$

7.7±0.5 PgC y$^{-1}$ + 4.1±0.1 PgC y$^{-1}$

2.4 PgC y$^{-1}$

26%

Calculated as the residual of all other flux components

2.3±0.4 PgC y$^{-1}$

27%

Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS
References cited in this ppt

- Carbon Dioxide Information Analyses Center (CDIAC). http://cdiac.ornl.gov/trends/emis/meth_reg.html