Carbon Budget 2008

GCP-Global Carbon Budget Consortium
Artist Impression of the Human Perturbation of the Carbon Cycle
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Fossil Fuel Emissions and Cement Production

[1 Pg = 1 Petagram = 1 Billion metric tonnes = 1 Gigatonne = 1x10^{15}g]

Le Quéré et al. 2009, Nature Geoscience; CDIAC 2009

2008:
Emissions: 8.7 PgC
Growth rate: 2.0%
1990 levels: +41%

2000-2008
Growth rate: 3.4%
CO₂ Fossil Fuel Emissions

- Annex B (Kyoto Protocol)
- Developed Nation
- Developing Nations
- Non-Annex B

1990 2000 2010

55%
45%
Fossil Fuel Emissions: Top Emitters (>4% of Total)

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

Time

Global Carbon Project 2009; Data: Gregg Marland, CDIAC 2009
Fossil Fuel Emissions: Profile Examples (1-4% of Total)

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

Time

1990 05 01 05 2008 07 99 03 03 05 2008

UK
Canada
South Africa
Australia
Spain
Brazil
Denmark

Global Carbon Project 2009; Data: Gregg Marland, CDIAC 2009
Balance of Emissions Embodied in Trade (BEET)

Year 2004

Warm colors $\rightarrow$ Net exporters of embodied carbon
Cold colors $\rightarrow$ Net importers of embodied carbon

MtC

BEET
Transport of Embodied Emissions

**CO₂ emissions (PgC y⁻¹)**

- **Annex B**
  - Developed Nations
  - Developing Nations
  - Non-Annex B

- **1990**
  - 55%
  - 25% growth

- **2000**
  - 45%

- **2010**

Cumulative Fraction of Total FF Emissions 2008

<table>
<thead>
<tr>
<th>Number of Countries</th>
<th>Country</th>
<th>Cumulative Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>.232</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>.419</td>
</tr>
<tr>
<td>3</td>
<td>India</td>
<td>.477</td>
</tr>
<tr>
<td>4</td>
<td>Russia</td>
<td>.530</td>
</tr>
<tr>
<td>5</td>
<td>Japan</td>
<td>.573</td>
</tr>
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<td>6</td>
<td>Germany</td>
<td>.599</td>
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<td>7</td>
<td>Canada</td>
<td>.617</td>
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<td>8</td>
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<td>.633</td>
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<tr>
<td>9</td>
<td>South Korea</td>
<td>.652</td>
</tr>
<tr>
<td>10</td>
<td>Iran</td>
<td>.668</td>
</tr>
<tr>
<td>20</td>
<td>Poland</td>
<td>.800</td>
</tr>
<tr>
<td>50 (2005)</td>
<td>Belarus</td>
<td>.941</td>
</tr>
<tr>
<td>100 (2005)</td>
<td>Moldova</td>
<td>.992</td>
</tr>
<tr>
<td>210</td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

- 3 countries: 50% Global Emissions
- 10 countries: 2/3 Global Emissions
- Top 5 + EU: 80% Global Emissions
Components of FF Emissions

Le Quéré et al. 2009, Nature Geoscience
Change in CO$_2$ Emissions from Coal Emissions

2006-2008

90% of growth
Per Capita CO₂ Emissions

Developed countries continue to lead with the highest emission per capita.
Fossil Fuel Emissions: Actual vs. IPCC Scenarios

Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature Geoscience; International Monetary Fund 2009
Economic Crisis Impact on World GDP Growth

-1.1%
Fossil Fuel Emissions: Actual vs. IPCC Scenarios

Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature Geoscience; International Monetary Fund 2009

Projection 2009
Emissions: -2.8%
GDP: -1.1%
C intensity: -1.7%

Full range of IPCC individual scenarios

Modified from Le Quéré et al. 2009
CO₂ Emissions from Land Use Change

![Graph showing CO₂ emissions from fossil fuel and land use change]

Net CO$_2$ Emissions from LUC in Tropical Countries

2000-2005

RA Houghton 2009, unpublished; Based on FAO Global Forest Resource Assessment
Emissions from Land Use Change (2000-2005)

Regional Emissions from LUC&F

- **Deforestation (Area)**
  - South & S.E. Asia: 25%
  - Tropical Africa: 35%
  - S. & Central America: 40%

- **C Flux**
  - South & S.E. Asia: 41%
  - Tropical Africa: 17%
  - S. & Central America: 43%

Canadell et al. 2009, Biogeosciences
Fire Emissions from Deforestation Zones

Global Fire Emissions Dataset (vs2)

van der Werf et al. 2006, Atmospheric Chemistry and Physics, updated
Total Anthropogenic Emissions 2008

CO₂ emissions (PgC y⁻¹)

- Fossil fuel
- Land use change


12% of total anthropogenic emissions

Atmospheric CO$_2$ Concentration

**Recent Global Monthly Mean CO$_2$**

**Year 2008**

385 ppm
38% above pre-industrial

**Annual Mean Growth Rate**

<table>
<thead>
<tr>
<th>Year</th>
<th>Rate</th>
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<tbody>
<tr>
<td>2008</td>
<td>1.79</td>
</tr>
<tr>
<td>2007</td>
<td>2.12</td>
</tr>
<tr>
<td>2006</td>
<td>1.77</td>
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<tr>
<td>2005</td>
<td>2.41</td>
</tr>
<tr>
<td>2004</td>
<td>1.62</td>
</tr>
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<td>2003</td>
<td>2.22</td>
</tr>
<tr>
<td>2002</td>
<td>2.40</td>
</tr>
<tr>
<td>2001</td>
<td>1.85</td>
</tr>
<tr>
<td>2000</td>
<td>1.24</td>
</tr>
</tbody>
</table>

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

**1970 – 1979:** 1.3 ppm y$^{-1}$
**1980 – 1989:** 1.6 ppm y$^{-1}$
**1990 – 1999:** 1.5 ppm y$^{-1}$
**2000 - 2008:** 1.9 ppm y$^{-1}$
Key Diagnostic of the Carbon Cycle

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

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

Total CO$_2$ emissions

Atmosphere

Data: NOAA, CDIAC; Le Quéré et al. 2009, Nature Geoscience
Airborne Fraction

Fraction of total CO$_2$ emissions that remains in the atmosphere

Trend: 0.27±0.2 % y$^{-1}$ (p=0.9)

40%

45%

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

Le Quéré et al. 2009, Nature Geoscience
Estimated Trends in Sea-Air pCO₂

1981-2007

Le Quéré et al. 2009, Nature Geoscience
Possible Reasons for a Positive Trend in Airborne Fraction

- Emissions are rising faster than the time scales regulating the rate of uptake by sinks.

- Sinks are becoming less efficient at high CO$_2$
  - Land: saturation of the CO$_2$ fertilization effect
  - Ocean: decrease in [carbonate] which buffers CO$_2$

- Land and/or ocean sinks are responding to climate change and variability.

- We are missing sink processes in models that are contributing to the observed changes.
Human Perturbation of the Global Carbon Budget

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

1850 1900 1950 2000

Sink: extra-tropics, tropics
Source: deforestation

2000-2008

1.4 PgC

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

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

Sink

Source

fossil fuel emissions

deforestation

Time (y)

2000-2008

7.7

1.4

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

<table>
<thead>
<tr>
<th>Sink</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>atmospheric CO₂</td>
<td>fossil fuel emissions</td>
</tr>
<tr>
<td>deforestation</td>
<td></td>
</tr>
</tbody>
</table>

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

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

Sink

Fossil fuel emissions
Deforestation
Atmospheric CO$_2$
Ocean

Source

2000-2008

7.7
1.4
4.1
2.3 (4 models)

Time (y)

1850
1900
1950
2000

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

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

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

### CO₂ flux (PgC y⁻¹)

<table>
<thead>
<tr>
<th>Sink</th>
<th>Source</th>
<th>Time (y)</th>
<th>2000-2008 PgC</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>fossil fuel emissions</td>
<td></td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>deforestation</td>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>atmospheric CO₂</td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>land</td>
<td></td>
<td>3.0 (5 models)</td>
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<tr>
<td></td>
<td>ocean</td>
<td></td>
<td>2.3 (4 models)</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td></td>
<td>0.3</td>
</tr>
</tbody>
</table>

Global Carbon Project 2009; Le Quéré et al. 2009, Nature Geoscience
Fate of Anthropogenic CO₂ Emissions (2000-2008)

1.4 PgC y⁻¹ + 7.7 PgC y⁻¹

4.1 PgC y⁻¹
45%

3.0 PgC y⁻¹
29%

2.3 PgC y⁻¹
26%

Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS, updated
Conclusions

• The efficiency of the natural sinks has been declining over the last 60 years, a trend not fully captured by climate models.

• The human perturbation of the carbon cycle continues to grow strongly and track the most carbon intensive scenarios of the IPCC. The economic crisis will likely have a transitional impact on the growth of CO₂ emissions and a undetectable effect on the growth of atmospheric CO₂ (because the much larger inter-annual variability of the natural sinks).
References cited in this ppt
