Today’s carbon cycle as revealed by observed CO$_2$ records

Pieter P. Tans
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CO₂ trend at Mauna Loa Observatory

Mole fraction (parts per million)

Year


Fossil fuel data: CDIAC and BP
DECADAL MASS BALANCE OF CARBON

Hamburg Ocean Carbon Cycle Model, E.Maier-Reimer, 1987

Pulse response:
\[ \text{CO2}_{\text{ATM}} = 0.131 + 0.201 \exp\left(-t/363\right) + 0.321 \exp\left(-t/74\right) + \]
\[ + 0.249 \exp\left(-t/17\right) + 0.098 \exp\left(-t/1.9\right) \]
DECADAL MASS BALANCE OF CARBON

sources: David Etheridge, CSIRO, Australia; ESRL
DECADAL MASS BALANCE OF CARBON

Cumulative fossil fuel emissions (Jan. 2007) 331 ± 25
  (source: CDIAC)

Observed atmospheric increase (Jan. 2007) 214 ± 8
  (source: ESRL)

Observed ocean increase through 1994 118 ± 19
  (Sabine et al., Science 2004)

Oceans, extrapolated through 2006 148

fossil fuel emissions + terrestrial sources = atmospheric increase + ocean
Use of isotopic ratios to distinguish sources

\[
\frac{^{13}\text{C}/^{12}\text{C}}_{\text{sample}} - \frac{^{13}\text{C}/^{12}\text{C}}_{\text{reference}}}{^{13}\text{C}/^{12}\text{C}}_{\text{reference}}
\]

<table>
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<th>Source</th>
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<td>From oceans</td>
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DECADAL MASS BALANCE OF CARBON

\[
\frac{^{13}C}{^{12}C} \text{ isotopic ratio of CO}_2
\]

Sources: Friedli (1986), Francey (1999), and ESRL & INSTAAR
DECADAL MASS BALANCE OF CARBON

rate of CO₂ injection into the atmosphere

- total
- 5-year smoothed
- fossil

net terrestrial emissions

billion metric ton carbon per year

1850 1900 1950 2000
Conclusion:

The observed increase in atmospheric carbon dioxide since pre-industrial times is entirely due to human activities.
CO2 GROWTH RATE and CLIMATE ANOMALIES

**global CO₂ growth rate**

- ppm/year
- 1995 - 2005

**global rate of decrease of δ¹³C**

- permil/year
- 1995 - 2005
CO2 GROWTH RATE and CLIMATE ANOMALIES

RECENT MONTHLY MEAN CO2 AT MAUNA LOA

www.esrl.noaa.gov/gmd/ccgg/trends/
CO2 GROWTH RATE and CLIMATE ANOMALIES
CO2 GROWTH RATE and CLIMATE ANOMALIES

global temperature anomalies (giss)

simulated global CO2 growth rate anomalies

response function

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CO2 GROWTHRATE and CLIMATE ANOMALIES

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**CO2 GROWTHRATE and CLIMATE ANOMALIES**

\[
\frac{d[CO_2]}{dt} = \int dt' \ R(t-t') \ \Delta T(t')
\]
CO2 GROWTH RATE and CLIMATE ANOMALIES

Response to global temperature anomalies

YEAR

CO2 GROWTH RATE (ppm/year/°C)

-10
-5
0
5
10
15
20
CO2 GROWTH RATE and CLIMATE ANOMALIES

Response to monthly mean precip anom

CO2 growthrate (ppm/year^2 per mm/day)

YEAR

0.0 0.5 1.0 1.5 2.0

0 5

-10 -15

-5
CO2 GROWTH RATE and CLIMATE ANOMALIES

CO2 growth rate anomalies (trend removed)

ppm/year

unexplained variations

ppm/year
Conclusion:

2/3 of the interannual variance of the CO2 growth rate is explained by the delayed response of the terrestrial biosphere to interannual variations of temperature and precipitation.