A brief history of the ESRL global carbon cycle observing system

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Carbon Cycle theme presentation
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Credits: Carbon Cycle Group and collaborators
Large-Scale Atmospheric Mixing As Deduced from the Seasonal and Meridional Variations of Carbon Dioxide

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Abstract. Representative data on the variations of carbon dioxide in the atmosphere are presented. The data reveal a presumably natural source in the tropical oceanic areas and the industrial source of midlatitudes. Using a simple model of large-scale exchange, the meridional eddy exchange coefficient is computed to be about $3 \times 10^{18} \text{ cm}^2 \text{ sec}^{-1}$, and the meridional transport from tropical to north polar areas is computed to be about $2 \times 10^{18}$ metric tons of carbon dioxide per year. An analysis of the seasonal variation shows that land vegetation north of $45^\circ \text{N}$ is responsible for a net consumption of carbon dioxide of about $1.5 \times 10^{18}$ tons during the vegetation period in summer. It is concluded that carbon dioxide is an excellent tracer for the study of atmospheric mixing processes. More data are needed, however, to make full use of it.

Introduction. Atmospheric CO$_2$ offers one of the most promising tracer constituents for elucidating atmospheric mixing processes on a global scale. The observed systematic variations of the content of CO$_2$ in the atmosphere with season, latitude, and altitude are the results of sources and sinks which exist only at the surface of the earth and which induce regular variations in the lowest layers of the atmosphere, the penetration of which upward and horizontally can yield quantitative information about the transfer mechanism of the atmospheric total observed variation, in spite of the high risk of contamination.

We shall discuss data obtained during 5 years (1957–1962) from pole to pole, primarily over the Pacific Ocean. The data are published in part [Keeling, 1960]; publication of the remainder is in progress.

From these data we will (1) give an over-all picture of the large-scale transfer processes in the troposphere and information on the main features of sources and sinks of CO$_2$; (2) establish how sensitive our conclusions are to the
1968  GMCC. Flask sampling at Niwot Ridge, CO  \( \text{CO}_2 \)
1976  4 continuous in-situ sites, 6 flask sites
1982  18 flask sites

5000 per year
1968  Flask sampling at Niwot Ridge, CO
1976  4 continuous in-situ sites, 6 flask sites
1982  18 flask sites
1988  26 flask sites, container ships
1990  Science paper: N.Hem. terr. carbon sink

CO₂

CH₄

CO, H₂

¹³C/¹²C, ¹⁸O/¹⁶O

5000 year⁻¹
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Data</th>
</tr>
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<tbody>
<tr>
<td>1968</td>
<td>flask sampling at Niwot Ridge, CO</td>
<td>CO₂</td>
</tr>
<tr>
<td>1976</td>
<td>4 continuous in-situ sites, 6 flask sites</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>12 flask sites</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>26 flask sites, container ships</td>
<td>CH₄</td>
</tr>
<tr>
<td>1990</td>
<td>Science paper: N.Hem. carbon sink</td>
<td>CO, H₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>¹³C/¹²C, ¹⁸O/¹⁶O</td>
</tr>
<tr>
<td>1992</td>
<td>in-situ CO₂ on 1st tall tower, aircraft sampling</td>
<td></td>
</tr>
</tbody>
</table>
WITN TV, Grifton, N.Carolina

Carr, Colorado
1968  Flask sampling at Niwot Ridge, CO  \( \text{CO}_2 \)
1976  4 continuous in-situ sites, 6 flask sites
1982  12 flask sites  \( \text{CH}_4 \)  \( 5000 \) per year
1983  \( \text{CH}_4 \)  \( \text{CO, H}_2 \)
1988  26 flask sites, container ships  \( \text{CO}_2, \text{H}_2, \text{CO}, \text{H}_2 \)  \( 13\text{C}/12\text{C}, 18\text{O}/16\text{O} \)
1990  Science paper: N.Hem. carbon sink
1992  In-situ CO\(_2\) on 1\(^{st}\) tall tower, aircraft sampling
1992  1st comparison program, with CSIRO
1992  Nature paper: CH\(_4\) increase slowing down
GLOBAL METHANE

Figure: Ed Dlugokencky
HISTORY OF NOAA/ESRL GREENHOUSE GAS OBSERVING SYSTEM

1968  Flask sampling at Niwot Ridge, CO  \( \text{CO}_2 \)
1976  4 continuous in-situ sites, 6 flask sites  \( \text{CH}_4 \)  \( \text{CO}, \text{H}_2 \)  \( ^{13}\text{C}/^{12}\text{C}, ^{18}\text{O}/^{16}\text{O} \)
1982  12 flask sites  5000 per year
1983
1988  26 flask sites, container ships  \( \text{N}_2\text{O}, \text{SF}_6 \)
1990  Science paper: N.Hem. carbon sink  \( ^{13}\text{C}/^{12}\text{C} \) of \( \text{CH}_4 \)
1992  In-situ \( \text{CO}_2 \) on 1st tall tower, aircraft sampling  \( ^{14}\text{CO}_2 \) 10,000
1992  Nature paper: \( \text{CH}_4 \) increase slowing down  D/H of \( \text{CH}_4 \), halocompounds
1992  1st comparison program, with CSIRO  \( \text{NMHCs} \)
1995  WMO \( \text{CO}_2 \) and \( \text{CO} \) calibration scales
1996  Globalview
1998
1998
1999
1999
2003  WMO calibration scale for \( \text{CH}_4 \)
2004  CarbonTracker
2005  7 tall towers, 15 aircraft sites  20,000
2007  11 comparison programs
2008
WMO goals for laboratory Intercomparability.

<table>
<thead>
<tr>
<th></th>
<th>target:</th>
<th>background</th>
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<tbody>
<tr>
<td>CO2</td>
<td>0.1 ppm</td>
<td>(385)</td>
</tr>
<tr>
<td>$^{13}$C/$^{12}$C</td>
<td>0.01 ‰</td>
<td></td>
</tr>
<tr>
<td>$^{18}$O/$^{16}$O</td>
<td>0.05 ‰</td>
<td></td>
</tr>
<tr>
<td>$^{14}$C/$^{12}$C</td>
<td>1 ‰</td>
<td>(1050)</td>
</tr>
<tr>
<td>CH4</td>
<td>2 ppb</td>
<td>(1780)</td>
</tr>
<tr>
<td>N2O</td>
<td>0.1 ppb</td>
<td>(322)</td>
</tr>
<tr>
<td>CO</td>
<td>2 ppb</td>
<td>(40-170)</td>
</tr>
<tr>
<td>H2</td>
<td>2 ppb</td>
<td>(480-550)</td>
</tr>
<tr>
<td>SF6</td>
<td>0.02 ppt</td>
<td>(6)</td>
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</table>
WHY HIGH ACCURACY MEASUREMENTS?

total column CO2, July 2005. (CarbonTracker)

carbontracker.noaa.gov
WHY HIGH ACCURACY MEASUREMENTS?

CO2, layer 1 – 3, July 2005. (CarbonTracker)

CO2 mole fraction (ppm)

365.5 368.5 371.5 374.5 377.5 380.5 383.5 386.5 389.5

carbontracker.noaa.gov
We have built an observing system combining high accuracy measurements and a data assimilation system. The observing system quantifies emissions and uptake or loss of greenhouse gases on the spatial scale of continents.

We play the central role in the international GHG monitoring program coordinated by the World Meteorological Organization (WMO).

There will be a need for objective quantification at smaller spatial scales, individual states and metropolitan areas. This requires a much denser measurement network, and much higher resolution transport models, especially surrounding observing sites.

There will likely be many institutions involved, and we are trying to get ready to take on an essential quality control and educational role.

A second essential task is to keep a close watch on climate feedbacks such as destabilization of Arctic permafrost. We need to intensify our observations in the Arctic.