CarbonTracker, a tool to quantify human and natural emissions of greenhouse gases based on atmospheric observations.

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Climate change and science

Mankind has become a major force transforming our planet in many ways. Climate change caused by human activities can be seen as a global experiment we are carrying out on our planet. Now that the human role is widely accepted as such, the role of science changes.

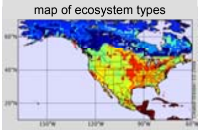
How can earth scientists serve society? We see four broad categories:

- Provide continuing ***diagnosis*** and understanding of the global experiment as it unfolds, with emphasis on "unexpected" feedback effects.
- Assist ***adaptation*** to climate change by providing useful predictions at regional and local scales, requiring a new generation of climate models.
- Assist ***mitigation*** of climate change by providing objective quantification of the degree of success of emissions limitations and sequestration.
- Provide thorough ***evaluation*** of potential geo-engineering schemes to counter climate change. Such schemes may well come to be regarded as compelling if (or when) panic breaks out in another one or two decades.

The methodology of CarbonTracker can be used to address the third and first categories by quantifying fossil fuel emissions, and by keeping track of how ecosystems and air-sea gas exchange evolve. For example, potential methane and carbon dioxide emissions from thawing permafrost in the Arctic could add substantially to further forcing of global climate change.

How does CarbonTracker work?

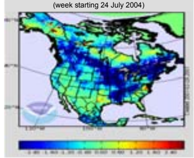
map of ecosystem types



ecosystem model

plus weather

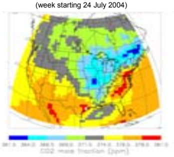
predicted fluxes (micromol m^{-2} s^{-1})
(week starting 24 July 2004)



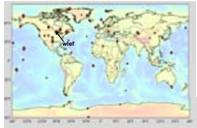
atmospheric

transport model

predicted CO2 in lowest 2 km
(week starting 24 July 2004)

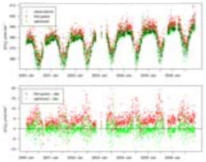


compare with high accuracy CO_2 observations



for example, at transmitter tower WLEF in N. Wisconsin

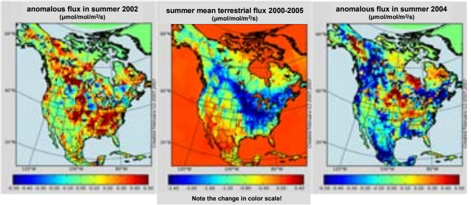
wlef, mid-afternoon, at 396 m



Adjust parameters of ecosystem flux models until modeled CO2 best matches the observations.

The optimization of terrestrial fluxes is shown here as an example. Ocean-atmosphere fluxes are similarly optimized based on atmospheric observations. Currently, two types of fluxes are held fixed: fossil fuel CO2 emissions and wildfire emissions.

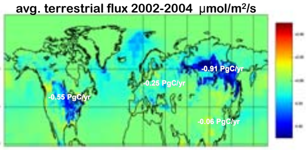
A result for North America:



Note the change in color scale!

A global result:

avg. terrestrial flux 2002-2004 μmol/m^2/s

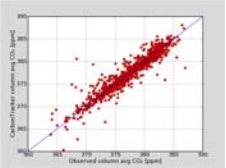


Top left: departures from the 6-year average summer flux in North America (shown in top center) during a drought year (2002)
Top right: departures from the average during a cooler summer (2004).
Blue colors indicate more uptake, and red colors indicate less uptake or even net emissions.

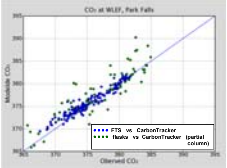
Bottom: 3 year average annual biospheric flux for the Northern hemisphere extra-tropics.

Reality check: comparison with independent data

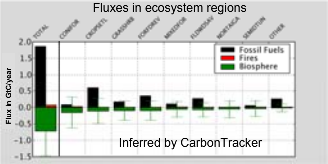
column CO_2 avg. from aircraft flasks



column CO_2 avg. from solar absorption data (FTS)



Fluxes in ecosystem regions



State of the Carbon Cycle Report (SAR 2.2, 2007):

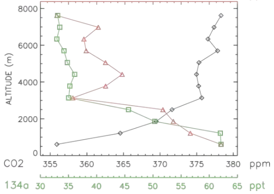
Forests	-0.23
Wood products	-0.07
Woody encroachment	-0.12
Agricultural soils	-0.01
Wetlands	-0.05
Rivers, reservoirs	-0.03

Exports:	
Wood products	-0.06
Agric. products	-0.07
rivers to oceans	-0.02

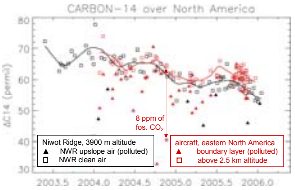
Total: -0.67 GtonCarbon/yr

Observations to quantify fossil fuel CO_2 emissions

Oglesby, Illinois, 9 August 2005



A typical summer vertical profile over the U.S. Midwest shows large depletion of CO_2 (black curve) in the boundary layer (< 3 km), due to recent photosynthesis by crops. Methane is enhanced toward the surface (red), due to recent/local sources. HFC-134a is also high (green). Its main use is in vehicle air conditioners. It is thus characteristic of traffic. CO_2 emissions from traffic are embedded in the CO_2 curve, and are partially compensating for the CO_2 drawdown by plants. If we know the average ratio of CO_2 to HFC-134a emissions for traffic we can quantify the traffic contribution to the observed CO_2.



Radiocarbon, or ^{14}C, is present in all living matter, but completely absent from fossil fuels. CO_2 produced from burning of fossil fuels lowers the $^{14}C/C$ ratio of ambient CO_2 in a precisely known way. Trace gases such as HFC-134a need to be correlated not with CO_2 itself, but with the ^{14}C depletion of CO_2. The measurement of a range of halocompounds and hydrocarbons will not only help quantify contributions to CO_2 emissions, but will also be very useful for policies aimed at reducing air pollution.

Large, but fairly isolated, cities such as Indianapolis or Minneapolis may offer an opportunity to have their emissions measured by mass balance through air sampling from aircraft and towers both upwind and downwind. Controlled releases of existing non-toxic perfluorinated compounds, for which exceedingly sensitive detection methods exist, could be considered.

14C figure: Jocelyn Turnbull and Scott Lehman, INSTAAR, U. of Colorado

Further developments of CarbonTracker

Provide independent quantitative estimates of emissions at **regional** scales and **urban** areas by:
Expanding the current density of observations. This is the most cost intensive element.
Using high-resolution transport/chemistry models and multiple chemical species.
Using very high resolution nesting around each observation site.

Use models of **fossil fuel burning** with parameters that are adjusted based on atmospheric observations. For example, electricity production (mostly coal burning) depends on demand for air conditioning. Space heating (oil and gas) also depends on temperature. Traffic has diurnal, weekly, and seasonal cycles.

Deploy detection systems for methane and carbon dioxide in **Arctic** regions, with emphasis on areas with a large amount of organic matter in the soils, and also where the permafrost is close to thawing.

Collaborate with **states and local** governments to make the high density of observations possible, while safeguarding the high accuracy required for greenhouse gas measurements. We are currently collaborating with Environment Canada, U. California Irvine, NCAR, Columbia U., Princeton, RIVM, IMAU, SRON (Netherlands), JRC (Italy), and Oak Ridge Nat. Lab.

Improve **uncertainty estimates** by using multiple chemistry/transport models and multiple emissions models.

Maintain our current policy of **complete** and prompt **openness** of all data and models to the public.

On the web http://CarbonTracker.noaa.gov

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