CarbonTracker - An annual global inversion flux product from the NOAA Earth System Research Laboratory

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Introduction

CarbonTracker is a combined measurement and modeling system that keeps track of the emissions and removal of atmospheric CO₂. Ecosystems in North America appear to have been net sinks of 0.7-4.3 PgC/yr during the 2000-2005 period, initially offsetting emissions of 1.9-2.5 PgC/yr from the burning of fossil fuels in the U.S., Canada and Mexico combined. Our estimates include sub-continenental patterns of sources/sinks coupled to the distribution of dominant ecosystem types across the continent.

The sinks are mainly located in the agricultural regions of the Midwest (35%), deciduous forests along the East Coast (32%), and boreal coniferous forests (25%). There also appears to be substantial interannual variation of the carbon sink, correlated with temperature and precipitations variations. Our estimates are optimally consistent with measurements of 14,000 air samples from across the world, ~5,000 daily averages from tall towers at four locations within the continent.

It is important to note that at this time the uncertainty estimate is itself quite uncertain. It has been derived from the formulation of the data assimilation system, which requires several “advanced guesses” for initial uncertainty estimates, and this has been used for different factors:

- The calculation is set up for sources/sinks to slowly revert to annual net zero in the absence of observational data, which may produce a bias.
- Due to the sparseness of data, we have had to define sink estimates for ecosystems across large distances, giving existing observations perhaps an undue amount of weight.
- The simulation sub-models for terrestrial photosynthesis and respiration is very “blind”, and will likely be greatly improved for the next release of CarbonTracker.

In upcoming versions of CarbonTracker, the addition of additional measurement sites is expected to lead to significant improvements. This will be especially evident in the sensitivity of estimated fluxes at smaller spatial scales.

Our Model of Observations

CarbonTracker finds optimal values for scalars that multiply high-resolution prior guess fluxes of CO₂ from available process models of the terrestrial biosphere and air-sea exchange. Observations of atmospheric CO₂ mixing ratios at available monitoring stations are modeled as:

\[ C = \sum_i \left( T_{i,0} + T_i + \frac{F_{i,0} + F_i - \lambda_{i,a} - \lambda_{i,f}}{\alpha_{i,0}} \right) \]

where \( T_{i,0} \) is modeled atmospheric transport working on the sum of fluxes due to the terrestrial biosphere (\( F_{i,b} \)), the ocean (\( F_{i,0} \)), and GFED (\( F_{i,0} \)). Our inversion technique uses the sum of \( T_{i,0} \) and \( \sum_i T_i \) only, and only the terrestrial biosphere and ocean fluxes are scaled by the factor \( \lambda \).

An optimization technique (a fixed-size ensemble Kalman smoother implemented within the TM5 atmospheric transport model) is used to find the unique values of \( \lambda \) that yield the smallest RMS difference between observed and modeled valued CO₂ mixing rates.

Optimization at the Ecosystem Scale

We optimize for land fluxes at sub-continental scales by dividing 11 large (TransCom) regions into independent ecosystems. For CarbonTracker 2006, we use 39 global ecosystems defined from version 1.5 of the Olson (1992) ecoregion product. Not all ecosystems are present in each TransCom region, and between the two North American (temperate and boreal) regions there are 24 independent ecosystems for which fluxes are optimized (see figure at right).

Modelled Atmospheric Transport

The TM5 transport model features 2-way grid nesting for high-resolution transport over selected regions. CarbonTracker 2006 is built on top of a global 6° x 5° grid (grids fines as left) and a 1° x 1° grid (blue) over most of North America. A 7° x 7° continental grid (red) is used to facilitate the nesting.

Evaluation: Match to Observations

CarbonTracker established using routine global-scale monitoring observations, in terms of long-term trends, the magnitude and timing of seasonal cycles, and interannual variations. High-latitude sites near Alaska and Antarctica were selected for their strong atmospheric CO₂ gradients, high latitudes, and least atmospheric mixing. High-latitude sites near Alaska and Antarctica were selected for their strong atmospheric CO₂ gradients, high latitudes, and least atmospheric mixing.

North American ecosystems appear to be a sink, with a net flux of 0.7 ± 0.9 PgC/yr. This is less than half the emissions due to fossil fuel use in the previous year. North America’s ecosystems vary such that the predictors of CO₂ emissions are often quite different.

Evaluation: Comparison with Aircraft Data

A “true” of the data assimilation system, since sources and sinks have been eliminated, is an estimate of the mole fraction of CO₂ in the atmosphere in every pixel of the model domain, including the boundary. The carbon sink is divided into two components: terrestrial and oceanic. The terrestrial component includes all sources and sinks, whereas the oceanic component includes all sources and sinks that involve the ocean. The terrestrial component includes all sources and sinks, whereas the oceanic component includes all sources and sinks that involve the ocean.

CarbonTracker 2006 observational network

The 24 ecoregions in North America

Results

Putting Your Ecosystem Model in CarbonTracker

For more information

Our Goal for Collaboration

References