A Latitudinal, Longitudinal, and Monthly Description of the Fossil-Fuel-Carbon-Dioxide Emissions for the Countries of the North American Carbon Program

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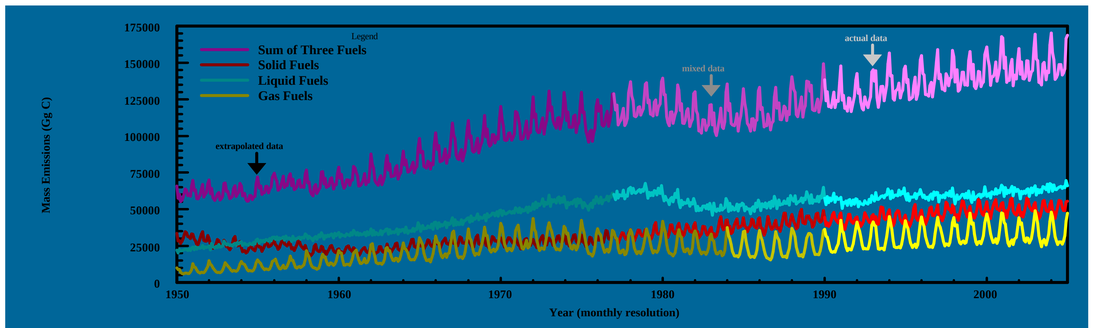
ABSTRACT A detailed, mechanistic understanding of the global carbon cycle needs description in multiple dimensions (e.g., fine spatial scales, fine temporal scales, accurate and precise mass fluxes, isotopic descriptions, etc.). Carbon dioxide emissions from fossil fuels are central to increased interest in the carbon cycle and are critical toward understanding other fluxes in the carbon cycle.

This presentation describes a subset of recent efforts that have produced a description of fossil-fuel-derived, carbon dioxide emissions at finer spatial and temporal scales than previously available. This subset focuses on the countries of the North American Carbon Program: Canada, the United States, and Mexico. Emission fluxes will be characterized in both mass and stable carbon isotope space.

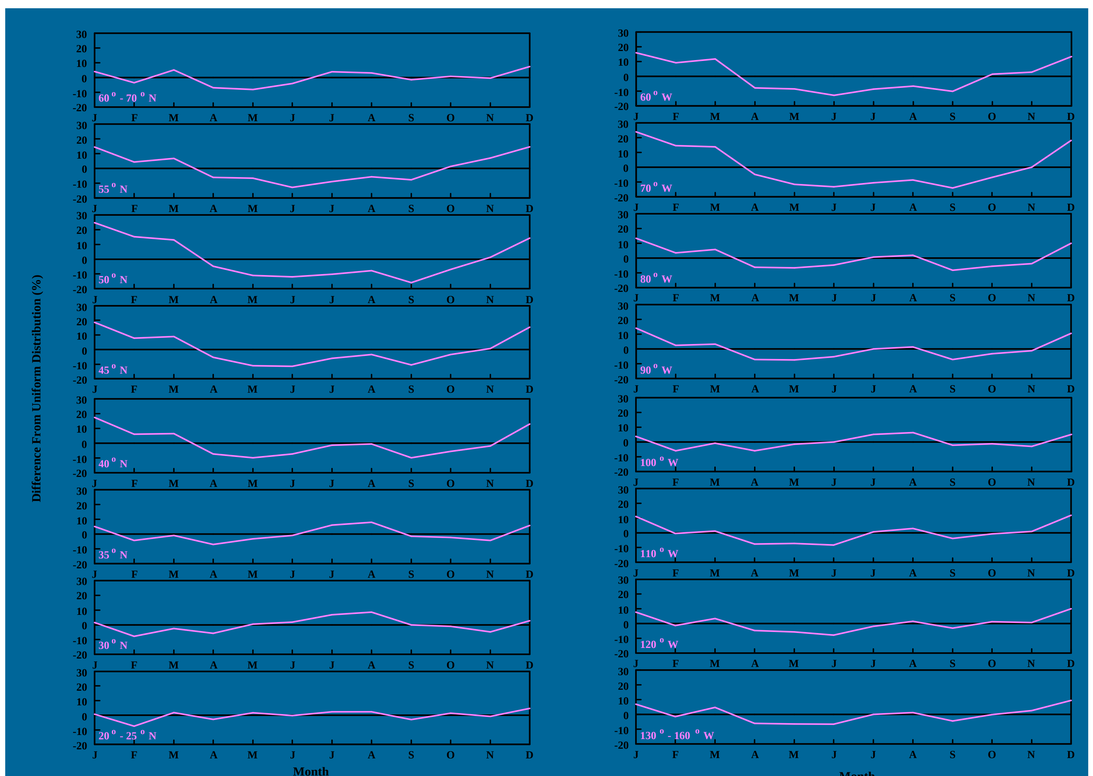
Past analyses of the monthly time series, in both mass and stable carbon isotope space, for individual countries have shown significant differences in the month-to-month emissions. For example, for the United States mass time series for the years 1984 to 2003, 46% of the months are statistically different at the 2-sigma level from the 1/12 approximation (a typical default distribution pattern obtained by dividing annual emissions equally among the 12 months).

Gregg et al. (submitted) have described North American emissions at monthly and state/province scales for the period 1990 to 2007. Monte Carlo simulations have now been used to extrapolate the extant data to years for which no data exist at the desired spatial and temporal scales. This has resulted in a time series for the years 1950 to the present. The Monte Carlo simulations have been conducted individually for gas, liquid and solid fuels. Emissions from gas flaring and cement manufacture are currently not included. These results, when combined with global carbon cycle models, should lead to a better understanding of the global carbon cycle.

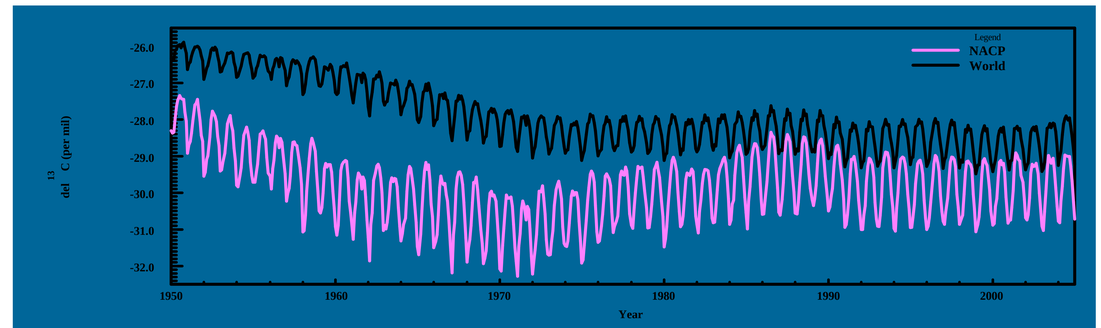
The work presented here is part of a larger effort which extended this type of analysis to 18 more countries around the world. Collectively, these 21 countries describe, explicitly, a majority of the total fossil-fuel-derived carbon dioxide emission flux. These 21 countries, via extrapolation, will be used to estimate the global fossil-fuel-derived carbon dioxide emission flux.



Graph 1 displays fossil fuel emission mass from the NACP countries for three fuels and their total (the CDIAC flux categories of gas flaring and cement are not included in this graph as monthly data for these two categories are not fully available for the NACP countries). The emission lines are further delineated by different line colors to denote times when actual data exist and extrapolations from that data are used. Also delineated are times when a mix of actual and extrapolated data are used (due to different data availability in the NACP countries).



Graph 2 displays the latitudinal and longitudinal mean monthly distributions of the total fossil fuel emissions shown in Graph 1. The difference from a uniform distribution (equal to 1/12 of the annual total in each month) is shown, given in percent. The data are shown for years 1990 to 2007 only. Tabular data are spread spatially by the geographic centroid of the smallest political unit (e.g., province in Canada, state in the U.S., and country in Mexico).

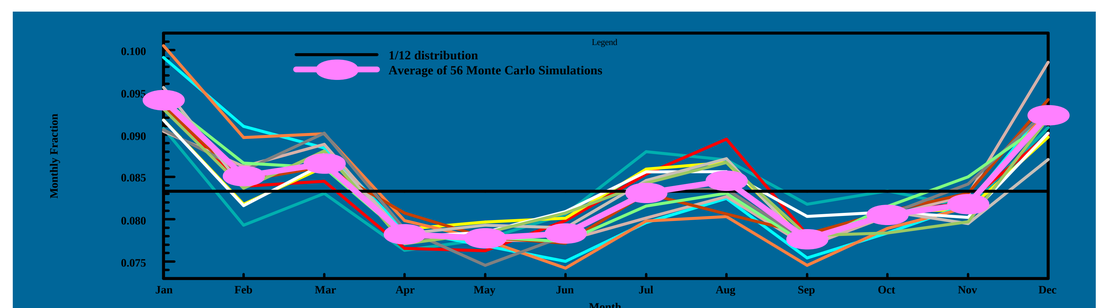


Graph 3 displays the calculated stable carbon isotopic signature of the NACP-country monthly emissions shown in Graph 1 as well as the corresponding curve for the entire world (these curves also include emissions from gas flaring and cement not shown in Graph 1). The NACP countries average 1.92 per mil lighter (become more negative) than the world, but the range of differences is –0.57 to –3.96 per mil. Both curves generally lighten with time because of the increasing use of natural gas in the fossil fuel mix.

The annual range of signatures also generally increases with time. While yet to be fully explored, this increased range reflects not only the changing mix of fossil fuels consumed with time, but also the concentrated use of some fuels during specific seasons.

The average annual range for del 13 C signatures over a given year for the entire 1950 to 2005 NACP data set is 1.92 per mil. The range in signatures spans 1.02 to 2.76 per mil. Corresponding average, minimum, and maximum ranges for the world are 1.04, 0.46, and 1.35 per mil.

The curves are lightest during the northern hemisphere's winter months and heaviest (less negative) during the northern hemisphere's summer months. This reflects the increased use of natural gas in the northern hemisphere during their winter.



Graph 4 displays 12 of 56 runs of the Monte Carlo simulation, the 1/12 flat distribution, and the average of those 56 runs. These 12 runs were chosen as they displayed minima or maxima in particular months for the NACP countries. The data show a statistically significant variation from a 1/12 assumed annual distribution (equal to 0.083). The pink symbols on the average line span approximately one standard deviation. Average data for nine of the 12 months lie outside plus or minus one standard deviation from an assumed 1/12 distribution. This decreases to six of 12 months being statistically different from a 1/12 distribution at plus or minus three standard deviations.

The data have been converted into monthly fractions for ease of interpretation.