Radiocarbon (^{14}C) Traces the Fossil and Biogenic Components of Total CO_2

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Δ^{14}C, the ratio of radiocarbon to total carbon, is a theoretically ideal tracer for recently added fossil fuel CO_2, because fossil fuel is ^{14}C-free. In contrast, all other carbon reservoirs that exchange CO_2 with the atmosphere, like the terrestrial biosphere and the oceans, are relatively rich in ^{14}C. Since 2004, NOAA ESRL and the University of Colorado Institute for Arctic and Alpine Research (INSTAAR) Radiocarbon Laboratory have worked together to make high precision (< 2 ‰) Δ^{14}C measurements. Our two sites in the eastern USA, Portsmouth, NH (NHA) and Cape May, NJ (CMA) exhibit large CO_2 signals from anthropogenic and biogenic fluxes. Using $\Delta^{14}CO_2$, however, we are able to partition the boundary layer CO_2 signal into biogenic and fossil fuel components. Once separated, these signals are independently useful. The biological signal can be used directly to infer the uptake and release of carbon by the biosphere, and the fossil signal can constrain anthropogenic emissions of CO_2, without the use of inventories, which can never be as recent as the measurements. Furthermore, the derived fossil fuel CO_2 signal is closely related to boundary layer enhancements of many air quality tracers like CO, SF_6, CFC-replacement compounds, and solvents like benzene. These relationships can exist for total CO_2, but we will show that they are biased because of the biogenic contribution. Having established a relationship between fossil fuel CO_2 and these tracers, we estimate their emissions by scaling the measured fossil-CO_2 tracer emission ratios to the well-known U.S. fossil fuel CO_2 inventory. Finally, we will show that a multi-tracer proxy of fossil CO_2 can be formed from the observed correlations. Such a multi-proxy tracer might serve as a low cost and widespread adjunct to actual ^{14}C observations.
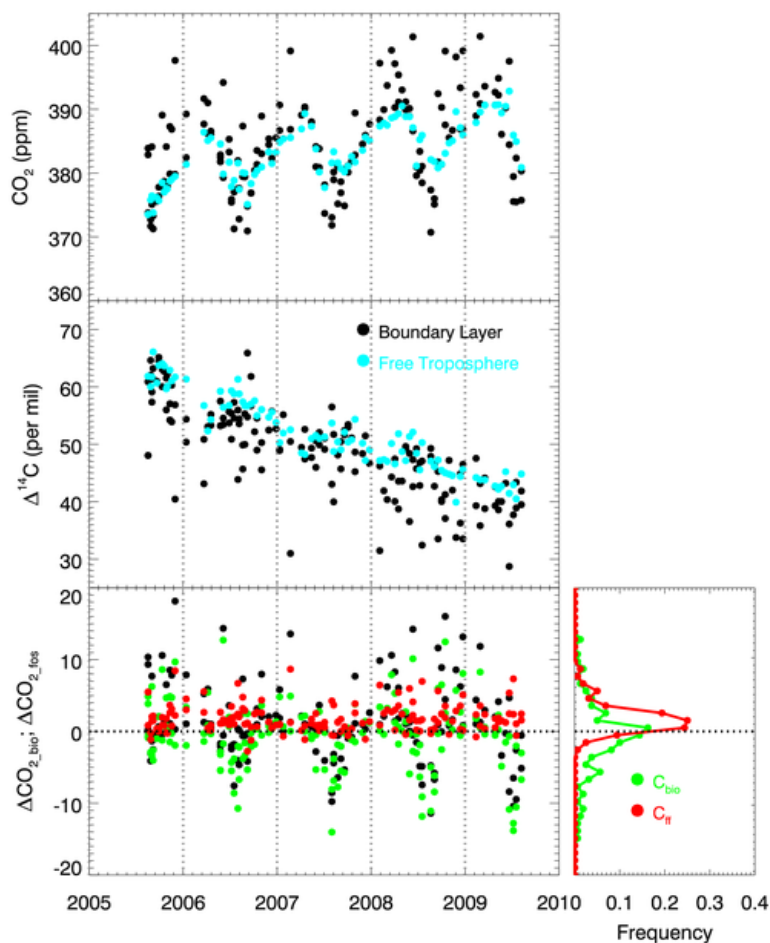

Figure 1. Fossil and biospheric CO_2 signals for boundary layer (PBL) aircraft air samples above (NHA) and (CMA). Top and middle panels show PBL (black) and a composite free troposphere (blue) reference time series for CO_2 and $\Delta^{14}CO_2$, respectively. Note that whereas for CO_2, the PBL values are both above and below the reference, for Δ^{14}C, the values are generally below the reference, showing the influence of fossil fuel emissions. The bottom panel shows the PBL-reference time series for CO_2 (black; C_{tot}) and the Δ^{14}C-derived values of the biological (green; C_{bio}) and fossil (red; C_{ff}) components. Even in winter, there are significant contributions from both biospheric and fossil fuel CO_2 to the total. In summer, C_{tot} underestimates the full extent of the photosynthetic drawdown of CO_2 shown by C_{bio}. The fourth panel shows the overall distribution of C_{bio} and C_{ff}.