

Measurement of atmospheric elemental carbon concentrations for the past about 150 years using Lake Sediments

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Atmospheric black carbon (BC) aerosols play a key role in the Earth's climate system through complex direct and indirect effects. Their estimated industrial-era total radiative forcing (RF) of +1.1 (+0.17 to +2.1) W m⁻² is the second largest after CO₂. BC may cause thinning of the Arctic ice and snow cover, affect global temperature, and human health. Since BC aerosols primarily exist as particles less than 100nm in diameter they can travel thousands of kms. Due to a lack of long-term BC data, climate models use emission estimates based on fuel consumption inventories as inputs for BC radiative forcing (RF) calculations, which represents a major source of uncertainty in BC RF estimates. Emission inventories have large uncertainties due to unreliable fuel consumption estimates, and a lack of historical data on forest fires and biomass burning. Thus, long term BC concentrations, [BC], data is needed to verify global model estimates of BC for multiple sites around the world. BC measurements in the atmosphere began only during the last few decades. The atmospheric deposition of BC in lake sediment provides means to retrieve atmospheric values over periods of centuries if BC atmospheric deposition rates in sediments are known.

BC is removed from the atmosphere mainly by precipitation and dry deposited. Husain *et al* (2008) showed that in an undisturbed lake [BC]_{sed}, is related to [BC]_{atm}, through the equation

$$[BC]_{sed} = K*[BC]_{atm} \quad (1)$$

where K is the deposition rate. If K is known [BC]_{sed} can be used to calculate past [BC]_{atm}. We determined annual [BC]_{atm} from monthly composites of daily samples collected from 1978 to 2012 at Whiteface Mountain, NY.

We also collected lake sediments cores from four remote high altitude lakes, West Pine Pond, (WPP), East Pine Pond (EPP), Boottree Pond (BTP), and Horseshoe Pond (HSP) using a freeze corer near Whiteface Mountain. The sediment cores were sliced, freeze dried, and ages determined using ²¹⁰Pb dating. The ²¹⁰Pb dating enables determination of ages for the past about 150 ages. The ages beyond about 1835 have been calculated using the mean sedimentation rate measured by this dating technique for the ~2012 to 1835 period. The uncertainties in the ages before ~1835, however, do not affect our conclusion regarding the [BC]_{atm} for the preindustrial period i.e., before about 1850. The data for samples listed as from 1725 to 1835 are definitely from the sediment deposited prior to 1850 as suggested by ²¹⁰Pb dating. BC was chemically separated in individual

samples, and quantified by the thermal-optical method (Husain *et al*, 2008). The [BC]_{atm} and [BC]_{sed} for the 1978- 2012 was used in equation (1) to determine K, which in turn was used to calculate back [BC]_{atm} from the lake sediments for the period prior to 1978. For a lack of space we discuss the data here for only two of the lakes, WPP, and EPP. [BC]_{atm} is around 100 ng m⁻³ at the present time (mean 2005–2010). Concentrations begin to increase, and peak ~1950, and decrease slowly to about 65 ng m⁻³ from 1850 to 1725. The mean [EC]_{atm} estimated from WPP for the period ~1700 - 1850 was found to be 62 ± 22 ng m⁻³, in excellent agreement with the value of 68 ± 19 ng m⁻³ found from EPP for the same period. From the results of [EC]_{atm} estimated from WPP and EPP, it could be concluded that the pre-industrial [EC]_{atm} was stable at around 65 ± 29 ng m⁻³, compared to about 100 ng m⁻³ at present.

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