Characterizing Carbonaceous Aerosols Transported to the Canadian Arctic: Attribution of Emission Sources of the Black Carbon at Alert

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Rationale:

- Linking aerosol carbon mass (e.g., black carbon mass) with its optical properties;
- Characterizing & attributing major emission sources of Black carbon;
Measurements at Alert (WMO_GAW Observatory)

Bi-weekly/weekly integrated quartz filters collected for
- Elemental carbon (BC mass) and organic carbon contents
- Related C isotopic compositions

In Situ measurements of light absorption coefficient (eBC)
- Hourly and weekly averaged values can be derived

Lin Huang et al, GMAC2015
Elemental Carbon (BC mass) & light absorption (BC optical property) at Alert

Lin Huang et al, GMAC2015
Inter-Annual Variation of Mass Absorption Coefficient (MAC) at Alert

\[ MAC = \frac{\sigma_{ap}}{C} \] (absorption per unit BC mass)

- MAC values during winter-spring seasons were pretty much constant as well as independent on particle size

\[ Modeled \ MAC_{BC} \ (at \ 550 \ nm) \ for \ uncoated \ sphere: \ 6.4 \ m^2/g, \ Adachi \ et \ al. \ [2010] \]
Elemental Carbon (BC mass) Measurements at Alert in comparison with the measurements at Beijing

Lin Huang et al, GMAC2015
$\delta^{13}C$ values of Possible Sources of Carbonaceous PM in the Earth System

- Fossil fuels
  - ~ - 40‰
  - ~ - 28‰
  - ~ - 24‰

- Biomass burning
  - ~ - 12‰

- C$_3$ Plants
  - ~ - 26‰

- C$_4$ Plants
  - ~ - 26‰

- Mantle Carbon
  - ~ - 5‰

- Carbonates (soil or sea salt)
  - ~ 0‰

Global & Regional 3FF Consumptions* & the mean $\delta^{13}C$ Values

- Global (-28.6‰)
  - 42% Gas (-40‰)
  - 19% Liquids Fuel and Gas (-28‰)
  - 40% Coal (-24‰)

- North America (-29.3‰)
  - 34% Gas (-40‰)
  - 22% Liquids Fuel and Gas (-28‰)
  - 44% Coal (-24‰)

- Euro-Rus (-31.2‰)
  - 29% Gas (-40‰)
  - 36% Liquids Fuel and Gas (-28‰)
  - 35% Coal (-24‰)

- Russia (-32.9‰)
  - 28% Gas (-40‰)
  - 21% Liquids Fuel and Gas (-28‰)
  - 51% Coal (-24‰)

- Asia (-26.1‰)
  - 66% Gas (-40‰)
  - 27% Liquids Fuel and Gas (-28‰)
  - 6% Coal (-24‰)

- China (-25.0‰)
  - 81% Gas (-40‰)
  - 17% Liquids Fuel and Gas (-28‰)
  - 2% Coal (-24‰)

Lin Huang et al, GMAC2015
$\delta^{13}C$ values of Possible Sources of Carbonaceous PM in the Earth System

Possible Sources of Carbonaceous PM in the Earth System:

- **Fossil fuels**
  - ~-40‰
  - ~-28‰
  - ~-24‰

- **Biomass burning**
  - ~-12‰

- **C$_3$ Plants**
  - ~-26‰

- **C$_4$ Plants**
  - ~-12‰

- **Carbonates (soil or sea salt)**
  - ~0‰
  - ~-5‰

- **Mantle Carbon**
  - ~5‰

$^{14}C$ is needed to separate modern C from fossil C!!

**Global** (-25.9‰)

- **North America** (-26.2‰)
  - Liq_fuel_D+G (-28‰)
  - Coal (-24‰)

- **Euro-Rus** (-26.2‰)

- **Asia** (-25.2‰)

- **Russia** (-25.7‰)

- **China** (-24.7‰)

*Lin Huang et al, GMAC2015*
Seasonal Variations of mean BC mass and its $\delta^{13}C$ at Alert

- Anti-correlation between $\delta^{13}C$ and BC mass in seasonal variation;
- Relatively negative values ($<-28$ permil) in $\delta^{13}C$ during winter-spring seasons, suggesting that gas flaring contributions to the BC are important at the Canadian arctic.
Opposite seasonal patterns in $\delta^{13}C$ at Alert & Beijing suggests that the aerosol BC transported to the Canadian arctic is not significantly influenced by the emissions sources from East Asia.
Inter-annual Changes of Seasonal means in $\delta^{13}C$ of “BC” mass at Alert (vs. Beijing, China)

- Changes in $\delta^{13}C_{EC}$ leaning toward more positive values during winter-spring seasons at Alert are observed;
- Satellite observations suggest that decreasing in gas flaring likely contributes to the changes;
- $^{14}C$ measurements need to be done to further confirm biomass burning /bio-fuel contributions.
Top 20 gas flaring countries

Source: NOAA satellite data; NOAA is currently processing 2013 data and working to calibrate the data to derive estimates of flare volumes. However, a number of circumstances, including the use of new VIIRS infrared technology for more accuracy, have delayed the process. The World Bank-led Global Gas Flaring Reduction Partnership and NOAA are working to make 2013 gas flare volume estimates available as soon as possible.

World Bank Group
Summary

- Opposite seasonal patterns in $\delta^{13}C$ at Alert & Beijing suggests that the surface aerosol BC transported to the Canadian arctic is not significantly influenced by the emissions sources from East Asia;

- Changes in $\delta^{13}C$ leaning toward more positive values during winter-spring seasons could be caused by either decreasing the fraction with relatively negative $\delta^{13}C$ values (e.g., gas flaring) or increasing the fraction with relatively positive $\delta^{13}C$ values (e.g. coal combustion or biomass burning);

- Satellite observations suggest that gas flaring activities in Russia, Kazakhstan and some other previous Soviet-Union countries have been decreased by ~ 30%, which may explain the positive trend in $\delta^{13}C$;

- The inter-annual variation of Mass Absorption Coefficient (MAC) & Absorption Angstrom Exponent (AAE) suggest that not much has been changed in optical properties over the period (2007-2011) and that the fraction of biomass burning contribution has not likely increased (no increasing trend in AAE observed). $^{14}C$ measurements need to be done to further confirm biomass burning contribution.
Thank you!
Elemental Carbon Contents at Alert vs. Fossil Fuel Consumption (2004 - 2012)

Lin Huang et al, GMAC2015
Inter-Annual Variation of Absorption Angstrom Exponent at Alert

\[ \bar{\lambda}_{\text{abs}} = - \frac{\log \left( \frac{\text{MAC}(\lambda_1)}{\text{MAC}(\lambda_2)} \right)}{\log(\lambda_1/\lambda_2)} \]

Lin Huang et al, GMAC2015