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;*

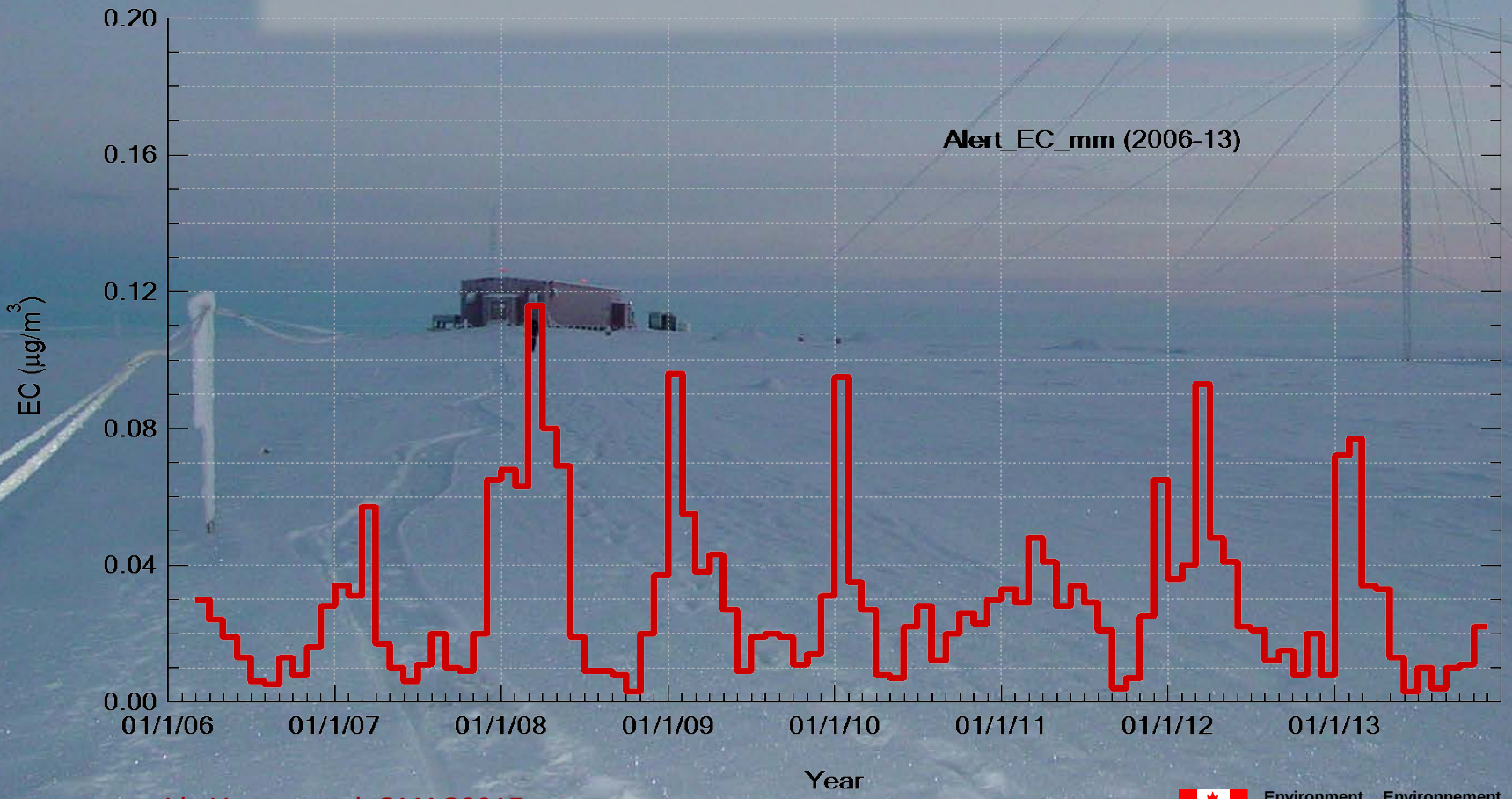
Measurements at Alert (WMO_GAW Observatory)

Bi-weekly/weekly integrated quartz filers 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



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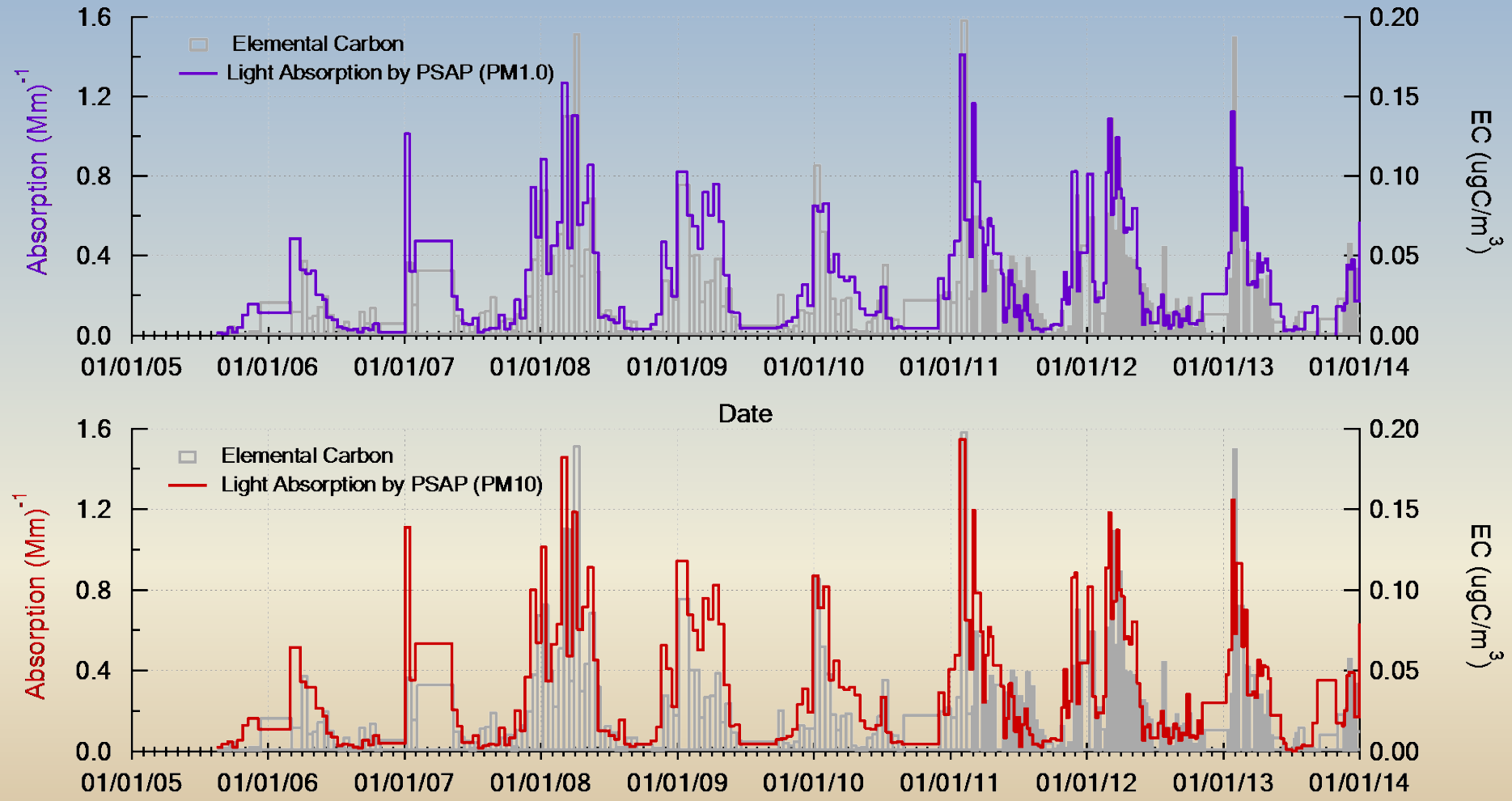
Elemental Carbon (BC mass) & **light absorption** (BC optical property) at Alert



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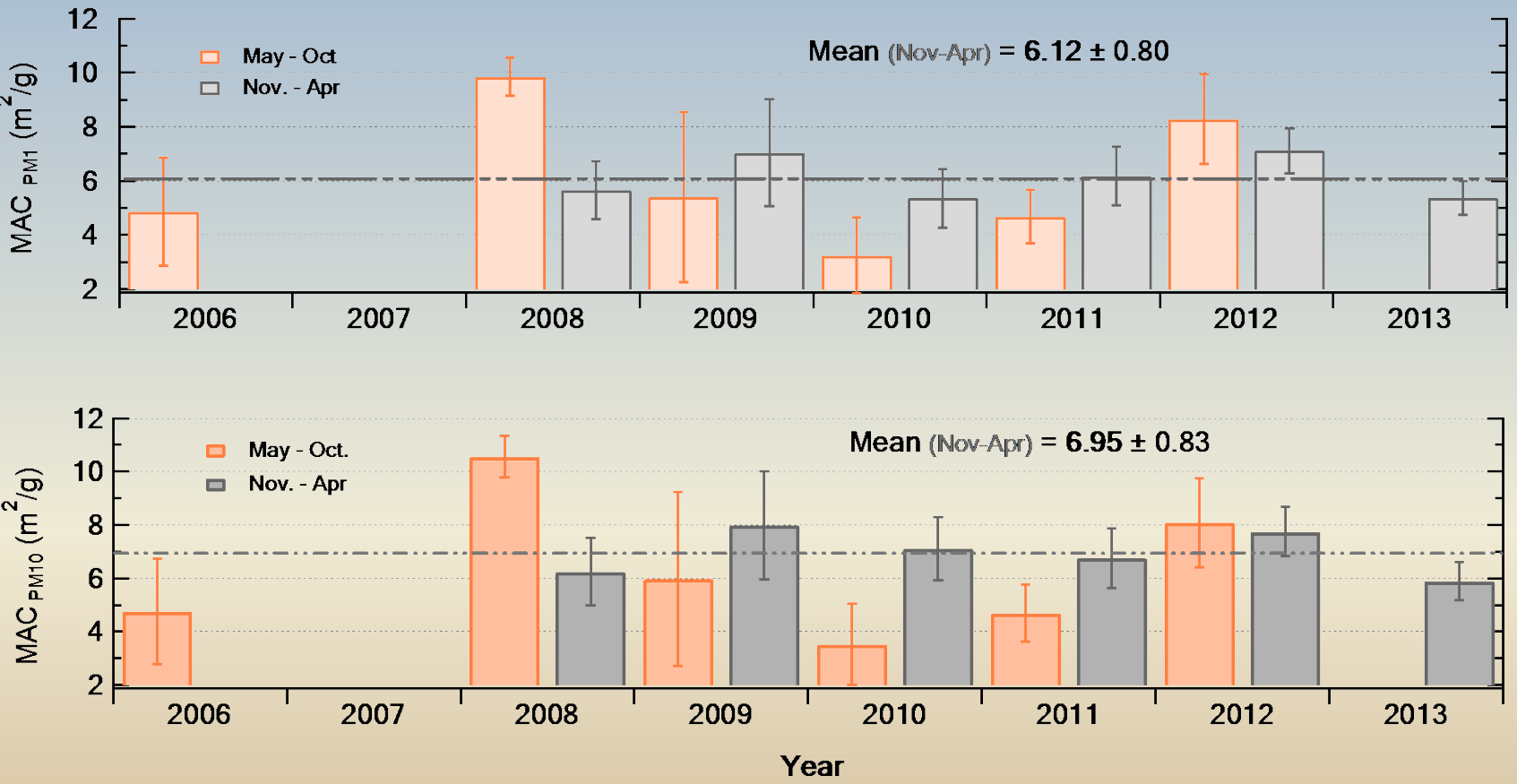
Inter-Annual Variation of Mass Absorption Coefficient (MAC) at Alert

MAC $= \sigma_{ap}/C$ (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]

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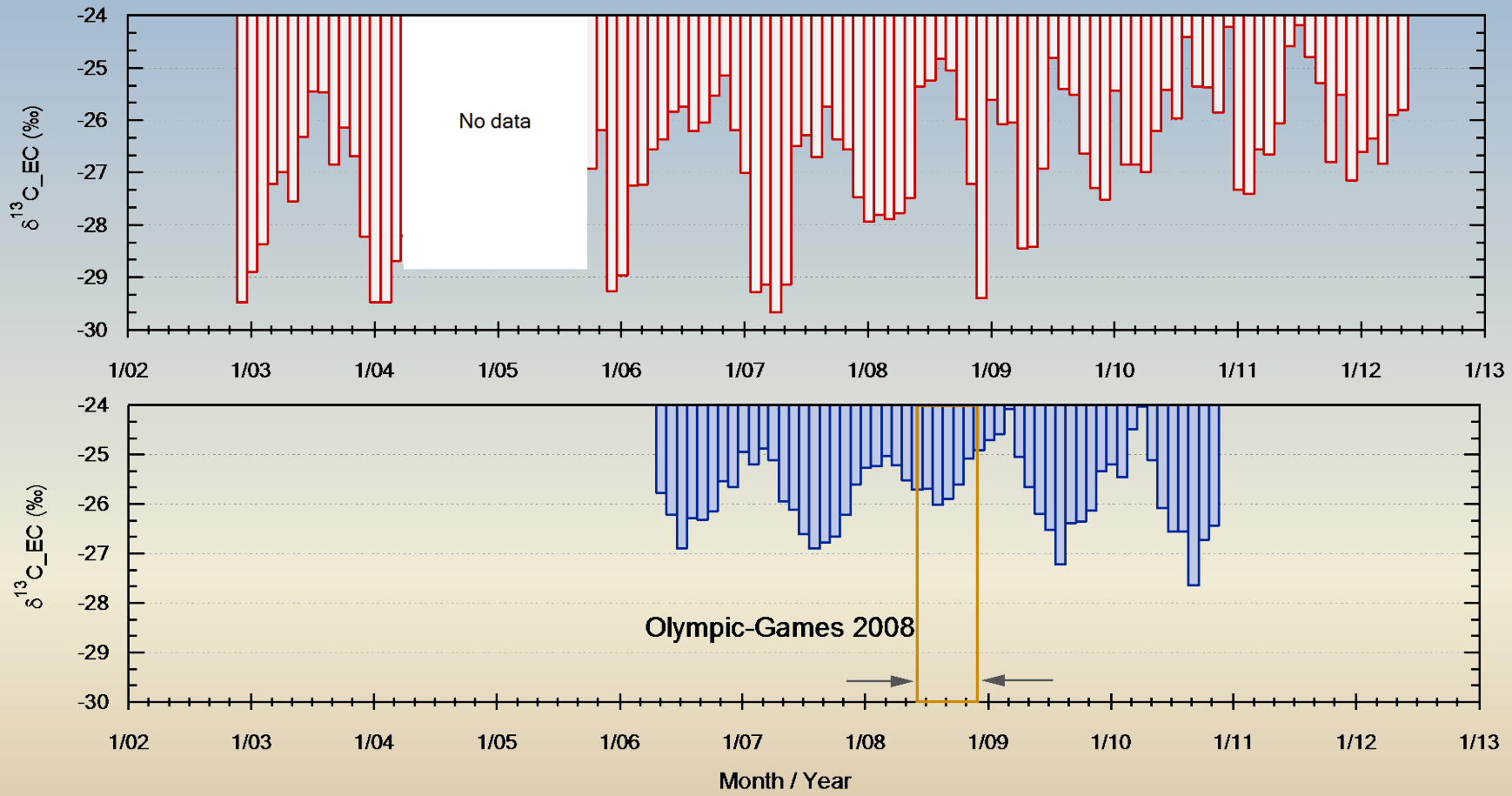
Elemental Carbon (BC mass) **Measurements at Alert**

in comparison with the measurements at Beijing



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$\delta^{13}C$ values of Possible Sources of Carbonaceous PM in the Earth System

~ - 5 ‰

Mantle Carbon

~ 0 ‰

Carbonates (soil or sea salt)

~ - 12 ‰

C_4 Plants

Biomass burning

~ - 26 ‰

C_3 Plants

~ - 40 ‰

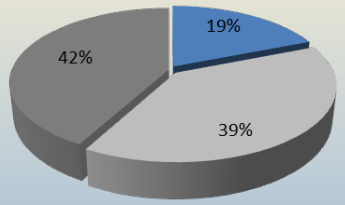
~ - 28 ‰

~ - 24 ‰

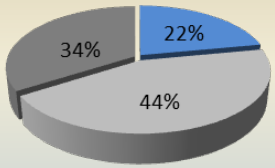
Fossil fuels

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

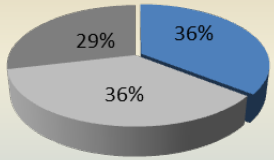
(*data source: http://cdiac.ornl.gov/trends/emis/overview for 2006)



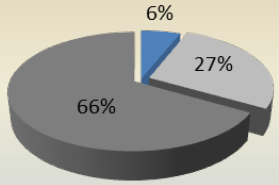
Global (-28.6 ‰)



North America (-29.3 ‰)



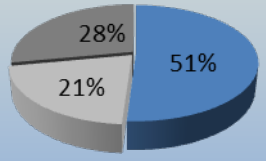
Euro-Rus (-31.2 ‰)



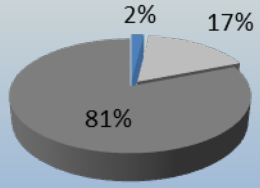
Asia (-26.1 ‰)

$\delta^{13}C$ of FF

- Gas (-40 ‰)
- Liq_fuel_D+G (-28 ‰)
- Coal (-24 ‰)



Russia (-32.9 ‰)



China (-25.0 ‰)

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$\delta^{13}C$ values of Possible Sources of Carbonaceous PM in the Earth System

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Mantle Carbon

~ 0 ‰

Carbonates (soil or sea salt)

~ - 12 ‰

C_4 Plants

Biomass burning

~ - 26 ‰

C_3 Plants

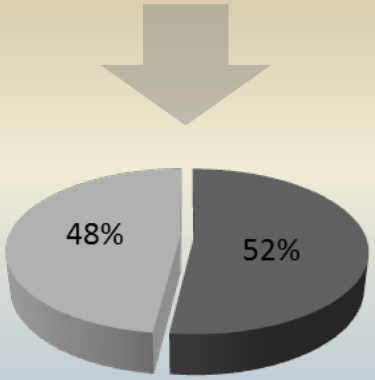
^{14}C is needed to separate modern C from fossil C !!

~ - 40 ‰

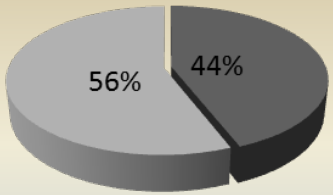
~ - 28 ‰

~ - 24 ‰

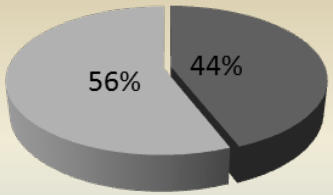
Fossil fuels



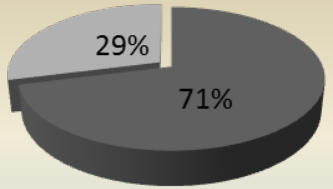
Global (-25.9 ‰)



North America (-26.2 ‰)



Euro-Rus (-26.2 ‰)

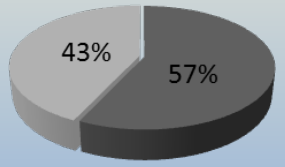


Asia (-25.2 ‰)

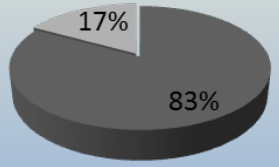
$\delta^{13}C$ of FF

Liq_fuel_D+G (-28 ‰)

Coal (-24 ‰)



Russia (-25.7 ‰)



China (-24.7 ‰)

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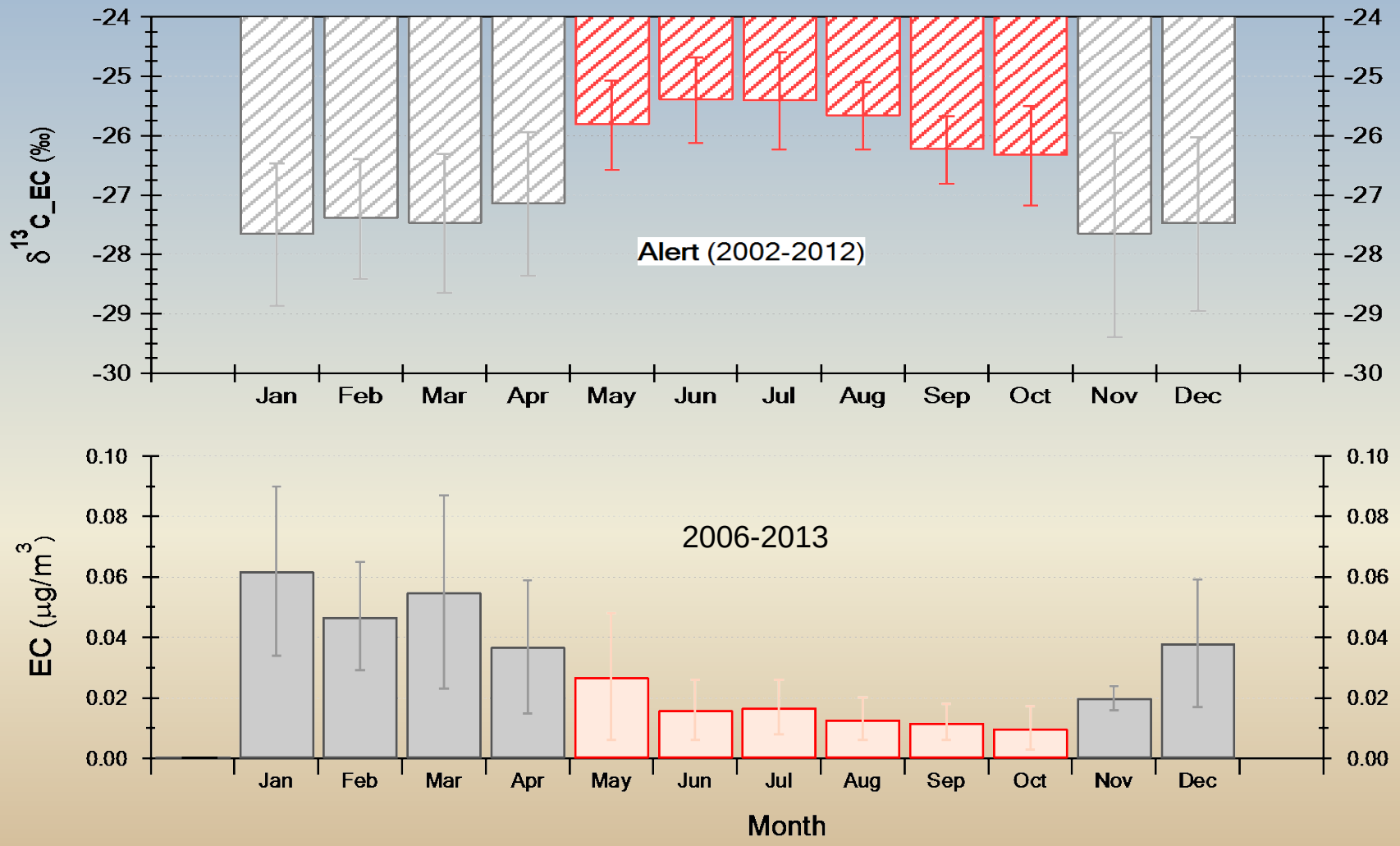
Seasonal Variations of mean BC mass and its $\delta^{13}C$ at Alert

- 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



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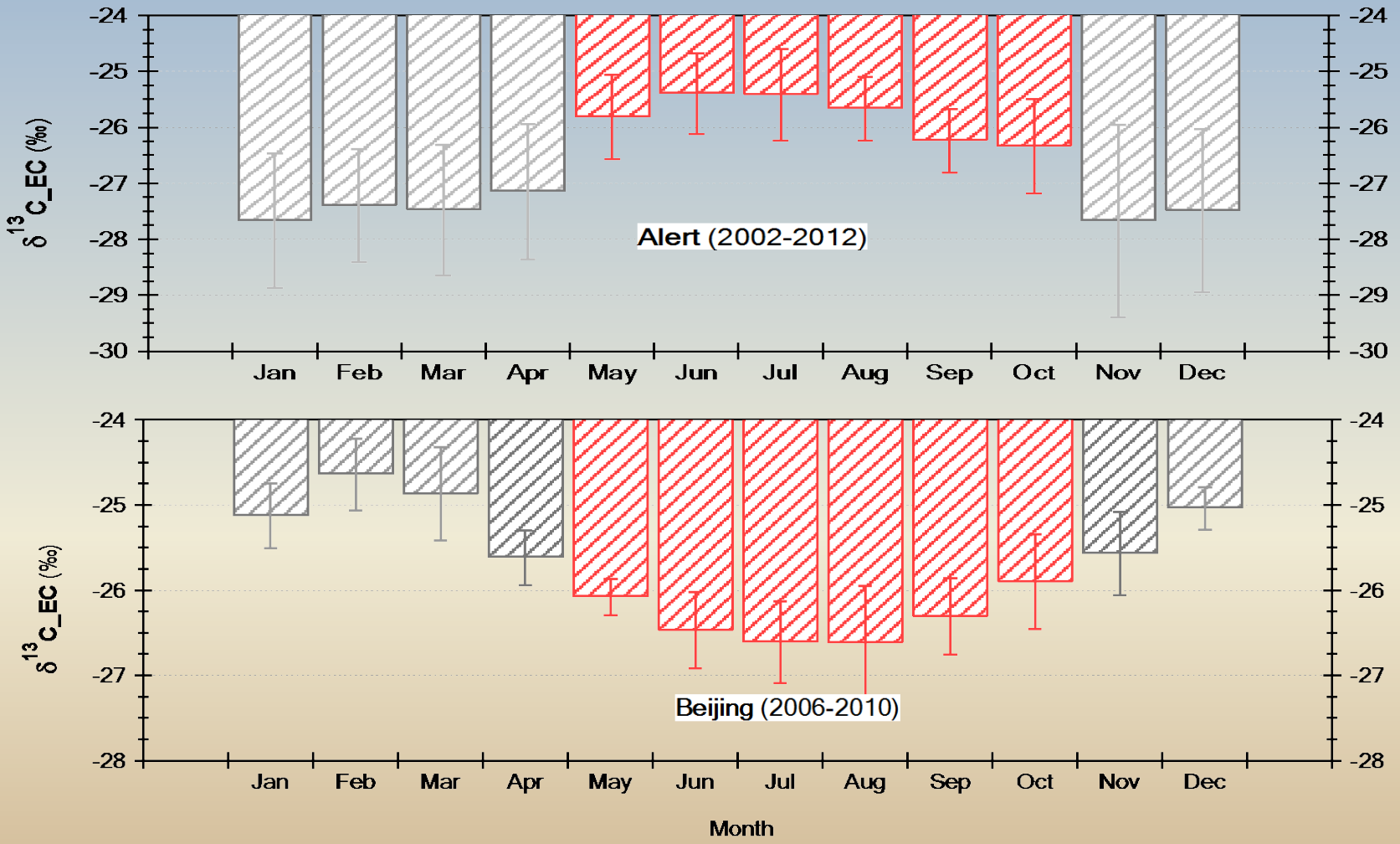
Seasonal Variations of means in $\delta^{13}C$ of Elemental Carbon

(Alert, Canada vs. Beijing, China)

- 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



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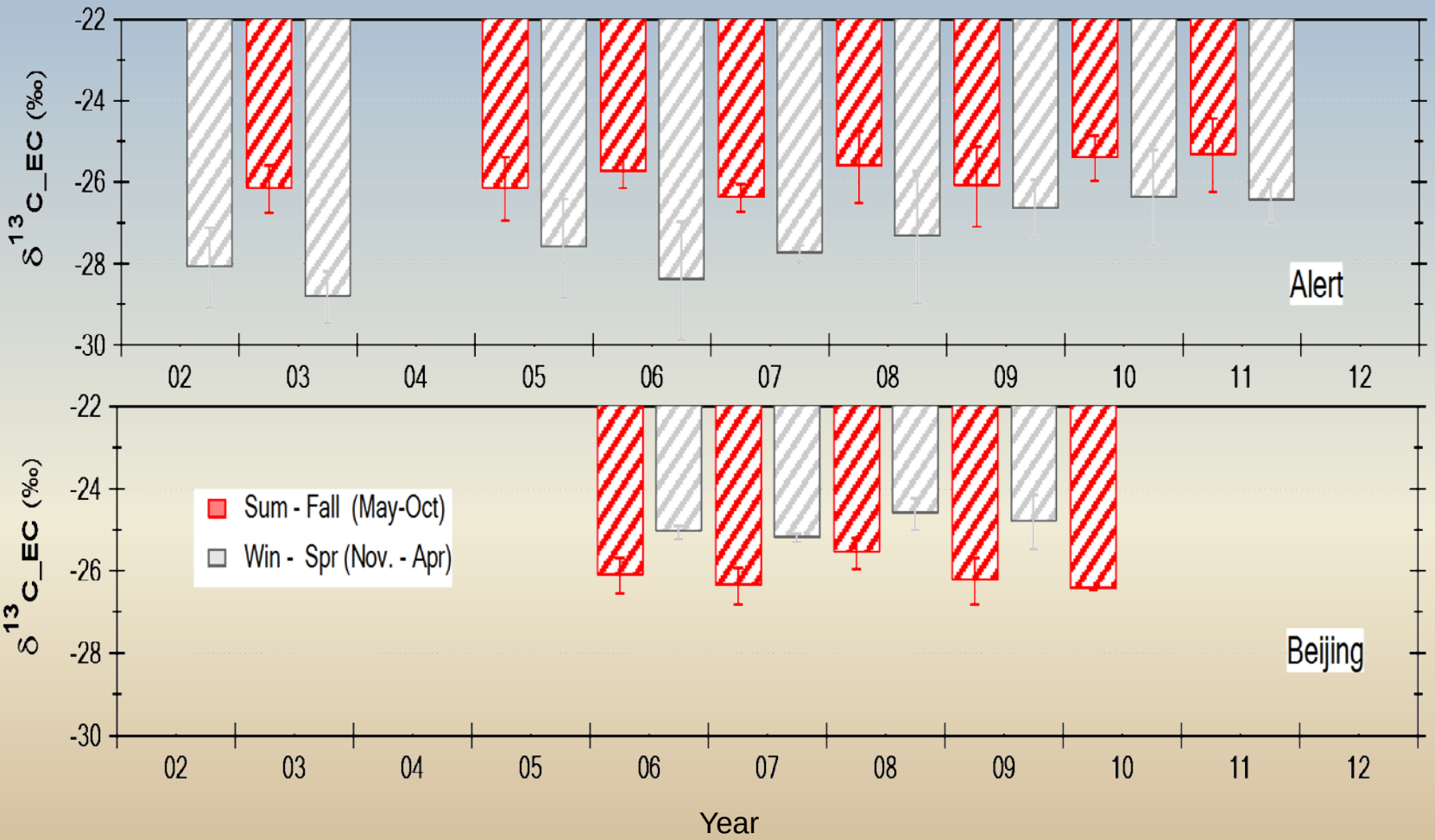
Inter-annual Changes of Seasonal means in $\delta^{13}C$ of "BC" mass at Alert

(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



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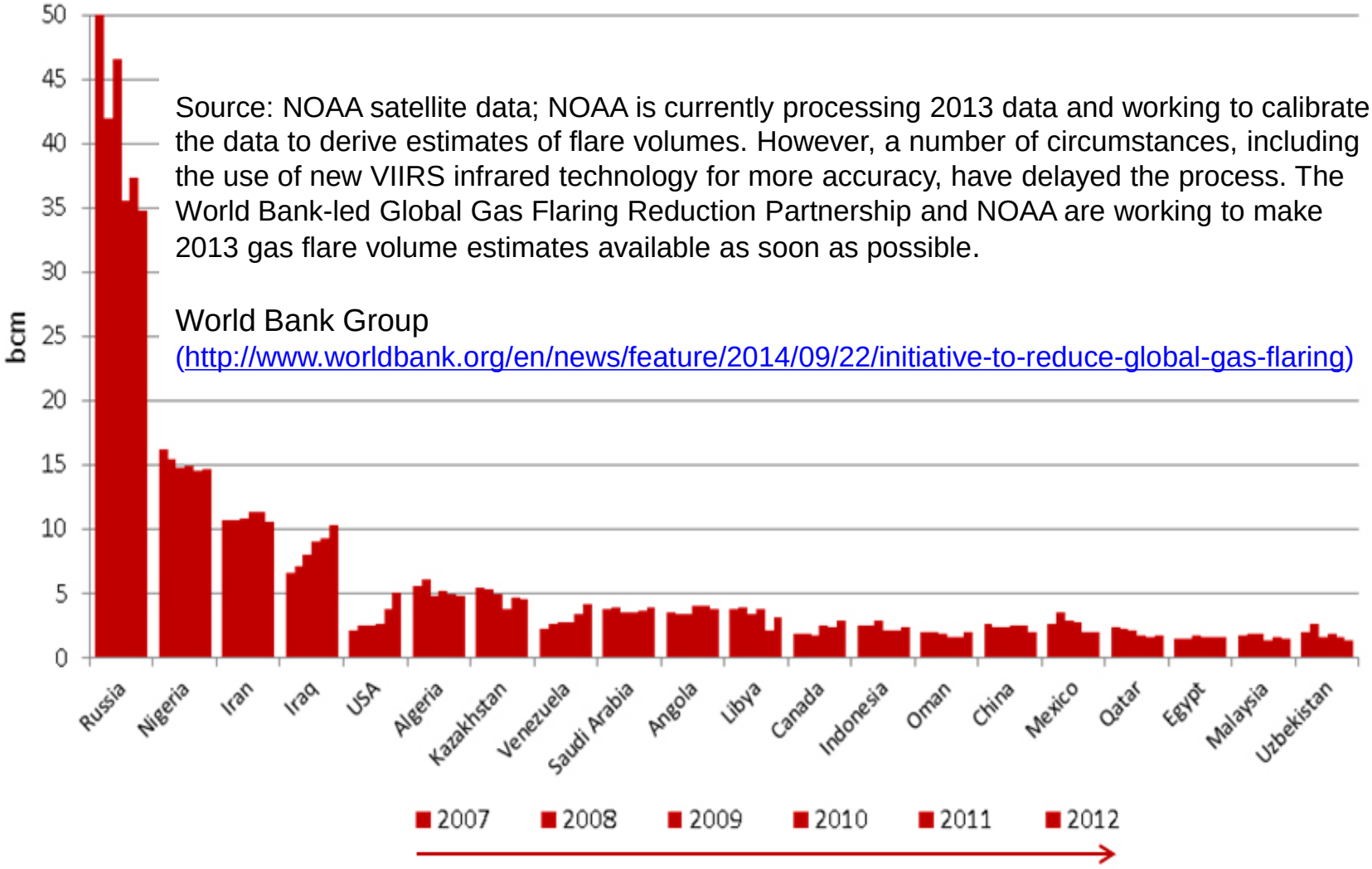
Top 20 gas flaring countries



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
(http://www.worldbank.org/en/news/feature/2014/09/22/initiative-to-reduce-global-gas-flaring)

Summary

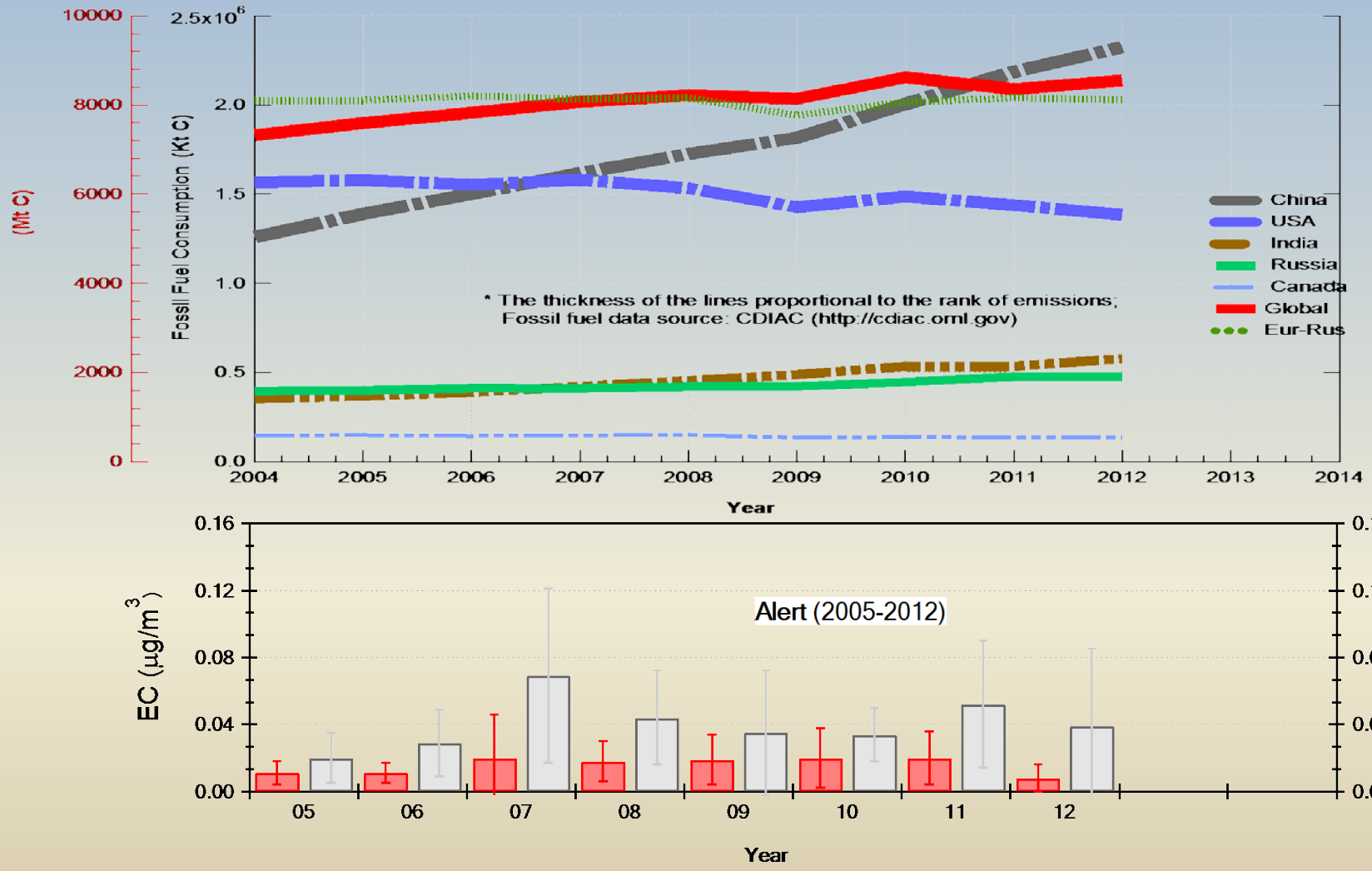
Photo by L Huang, 2004

- 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 !

Photo from the CO of the base at Alert, 2004

Elemental Carbon Contents at Alert vs. Fossil Fuel Consumption (2004 - 2012)



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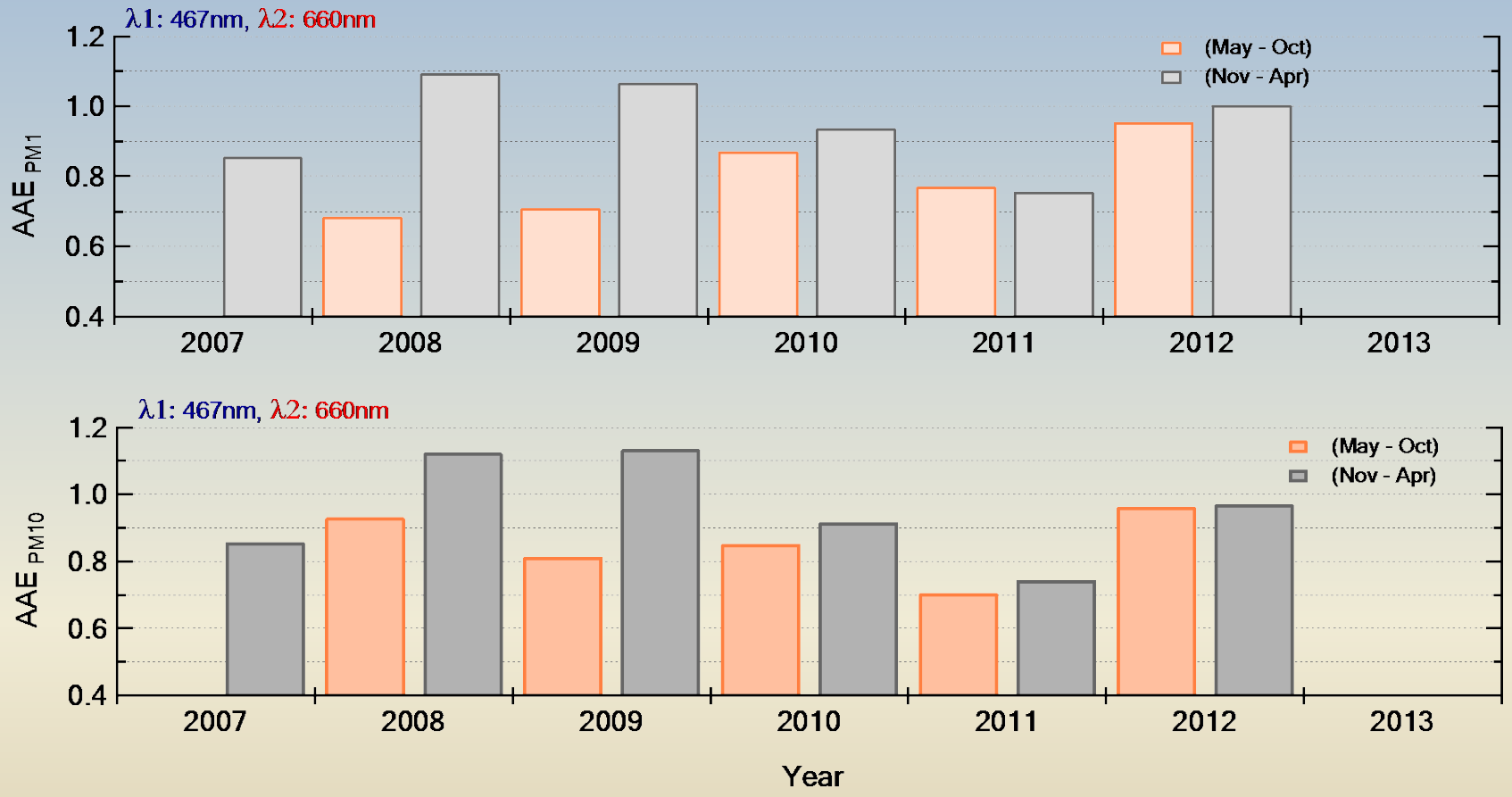
Inter-Annual Variation of **A**bsorption **A**ngstrom Exponent at Alert



$$Å_{abs} = - \{Log [MAC(\lambda 1) / MAC(\lambda 2)] / Log(\lambda 1/\lambda 2)\}$$

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