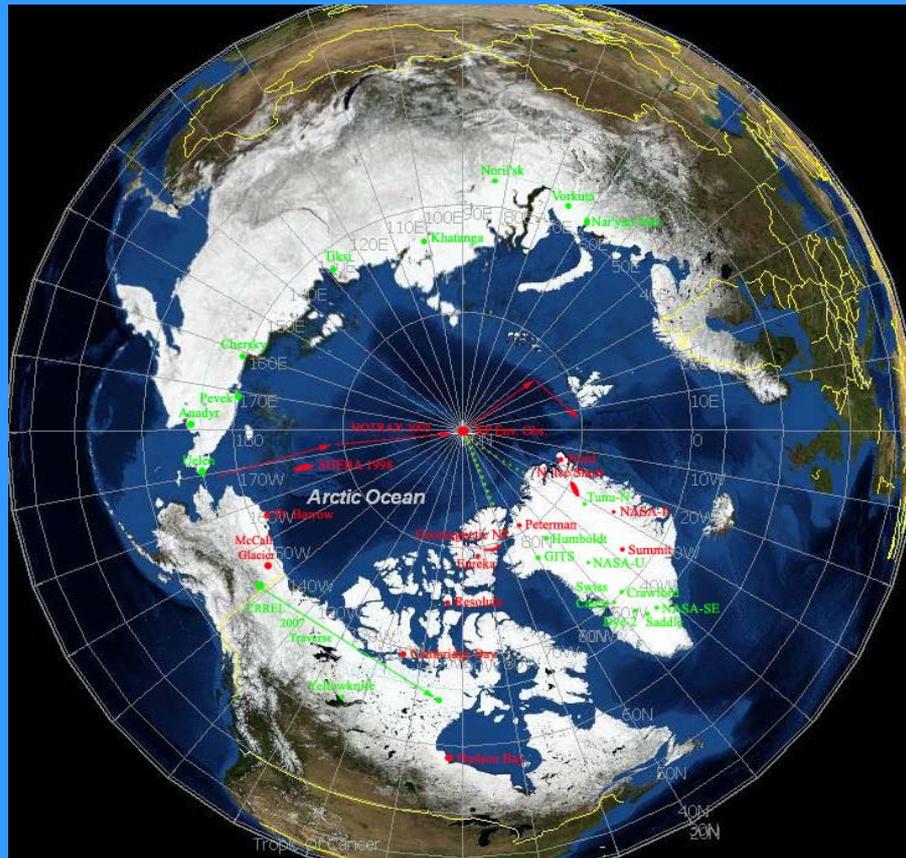


Source Attribution of Light Absorbing Aerosol in Arctic Snow

(Preliminary analysis of 2008-2009 data)



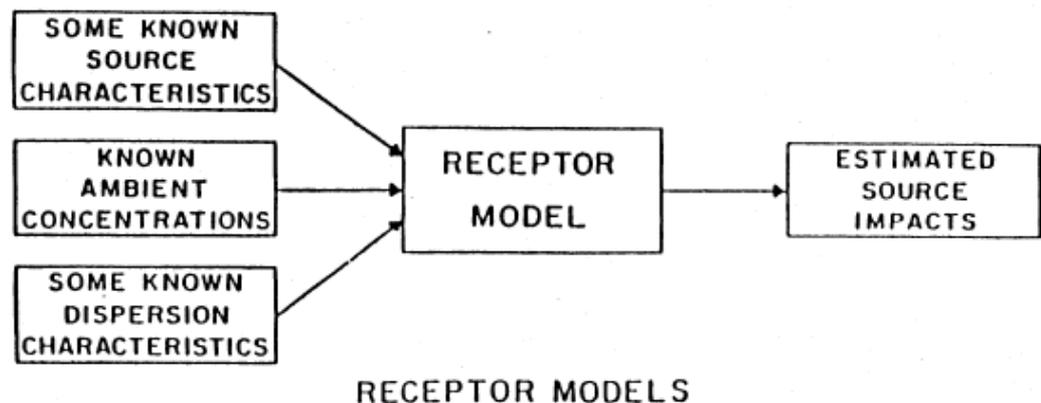
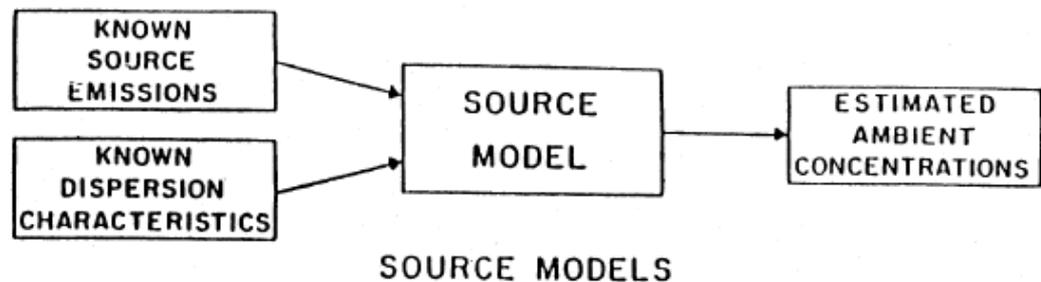
Outline

- Receptor modeling overview
- Results from 2007 data set
- New goals arising from analysis of 2007 data
- New data for 2008
- New data for 2009
- Tentative conclusions
- Future analysis

Source Model versus Receptor Model

A Basic Schematic

- The source model uses source emissions as inputs and calculates ambient concentrations
- The receptor model uses ambient concentrations as inputs and calculates source contributions



Conservation of Mass

$$C_{ij} = \sum_{k=1}^p g_{ik} f_{kj}$$

$i = 1, \dots, n$ samples,
 $k = 1, \dots, p$ sources and
 $j = 1, \dots, m$ species

C_{ij} = airborne concentration of species j observed in the i^{th} sample at a "receptor" location (e.g. community air monitoring site)

g_{jk} = airborne concentration of total fine particle mass contributed by source k to the i^{th} sample at the receptor

f_{kj} = mass fraction of species j in fine particles emitted from source k

Positive Matrix Factorization: a weighted least squares solution

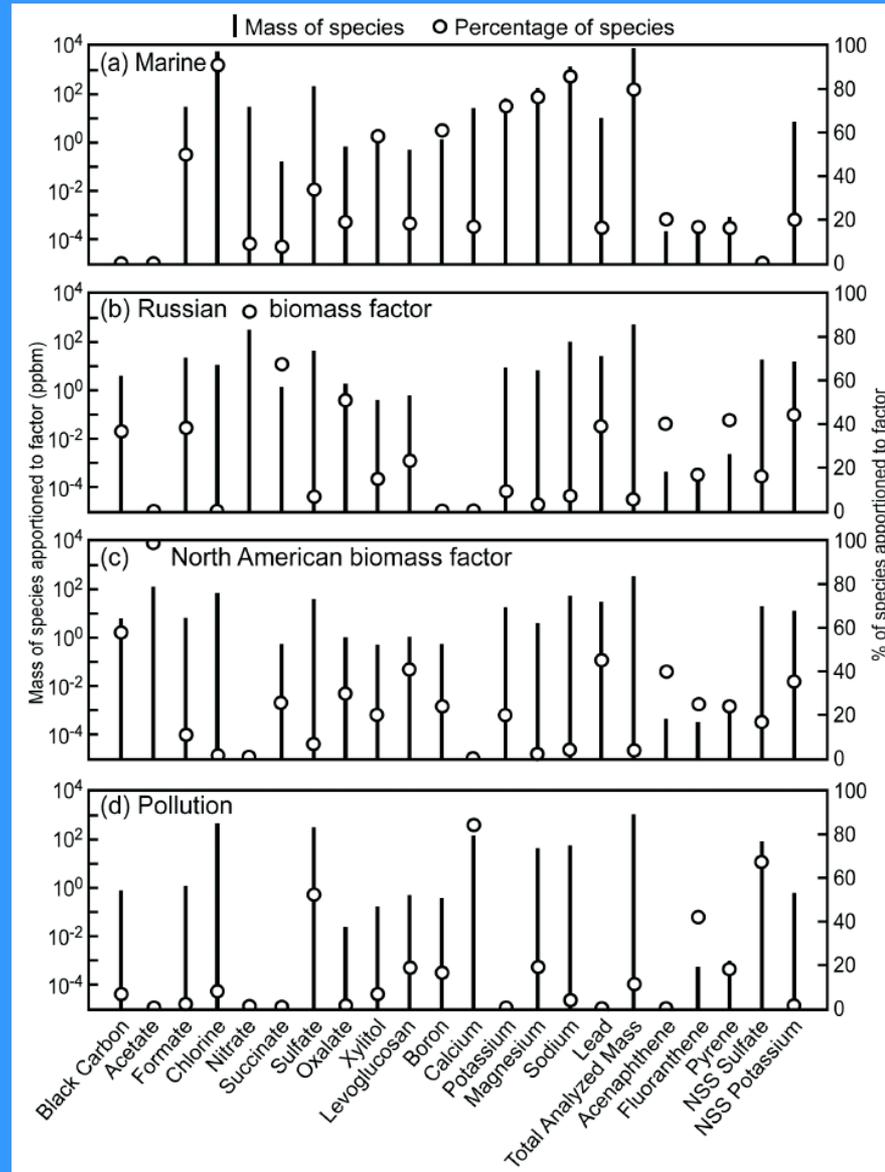
PMF provides a least squares solution to the basic receptor equation:

$$C_{ij} = \sum_{k=1}^p g_{ik} f_{kj} + \varepsilon_{ij}$$

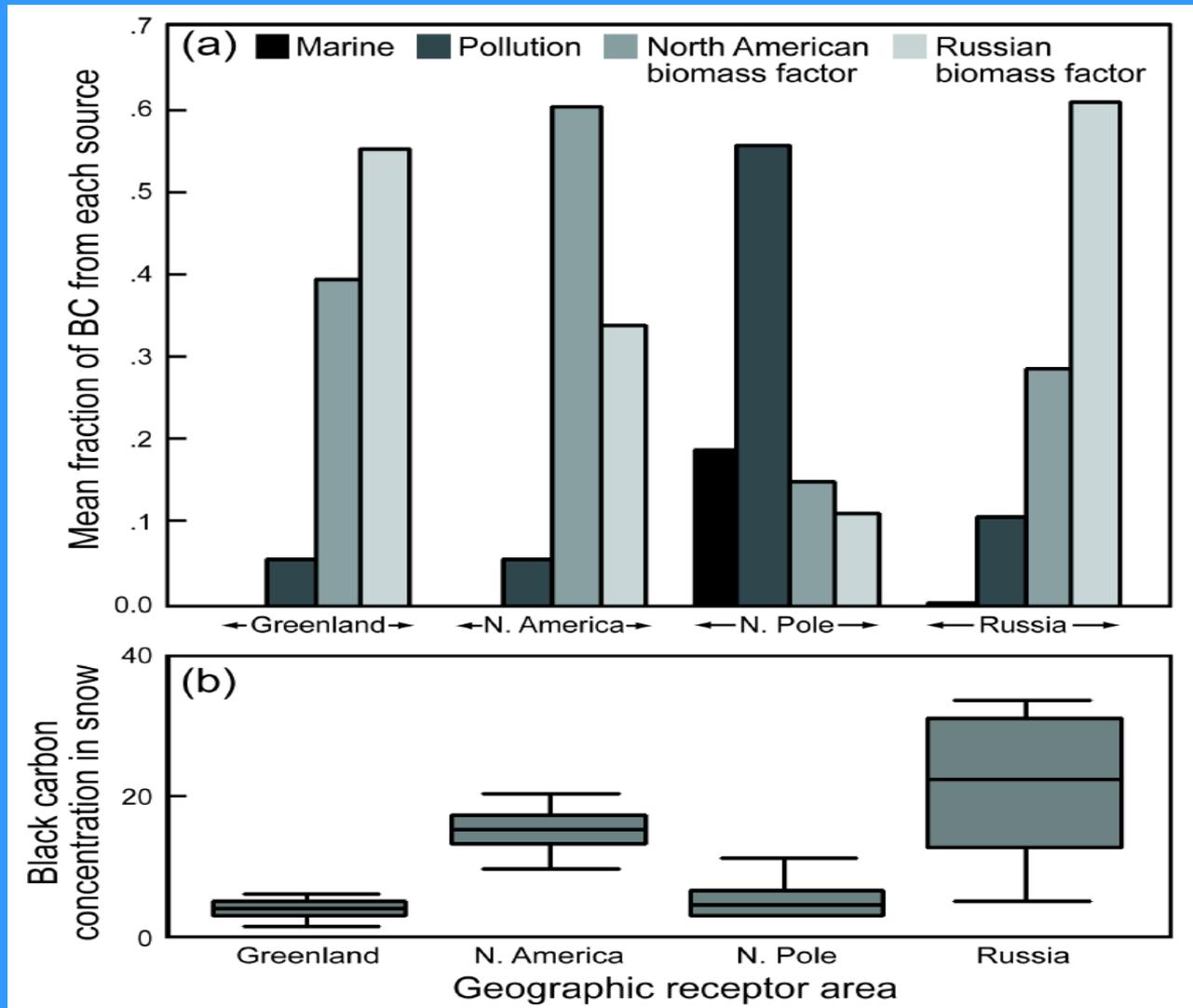
Specifically, PMF minimizes an object function, $Q(E)$, based upon analytical uncertainties for each observation.

$$Q(E) = \sum_{i=1}^n \sum_{j=1}^m \left[\frac{C_{ij} - \sum_{k=1}^p g_{ik} f_{kj}}{\sigma_{ij}} \right]^2 + \left(\begin{array}{l} \text{penalty} \\ \text{terms to} \\ \text{restrict the} \\ \text{solution to} \\ \text{positive} \\ \text{values} \end{array} \right) + \left(\begin{array}{l} \text{additional} \\ \text{terms to} \\ \text{minimize} \\ \text{rotational} \\ \text{ambiguity} \end{array} \right)$$

Factor profiles from 2007 analysis



Source attribution of Black Carbon from 2007 analysis



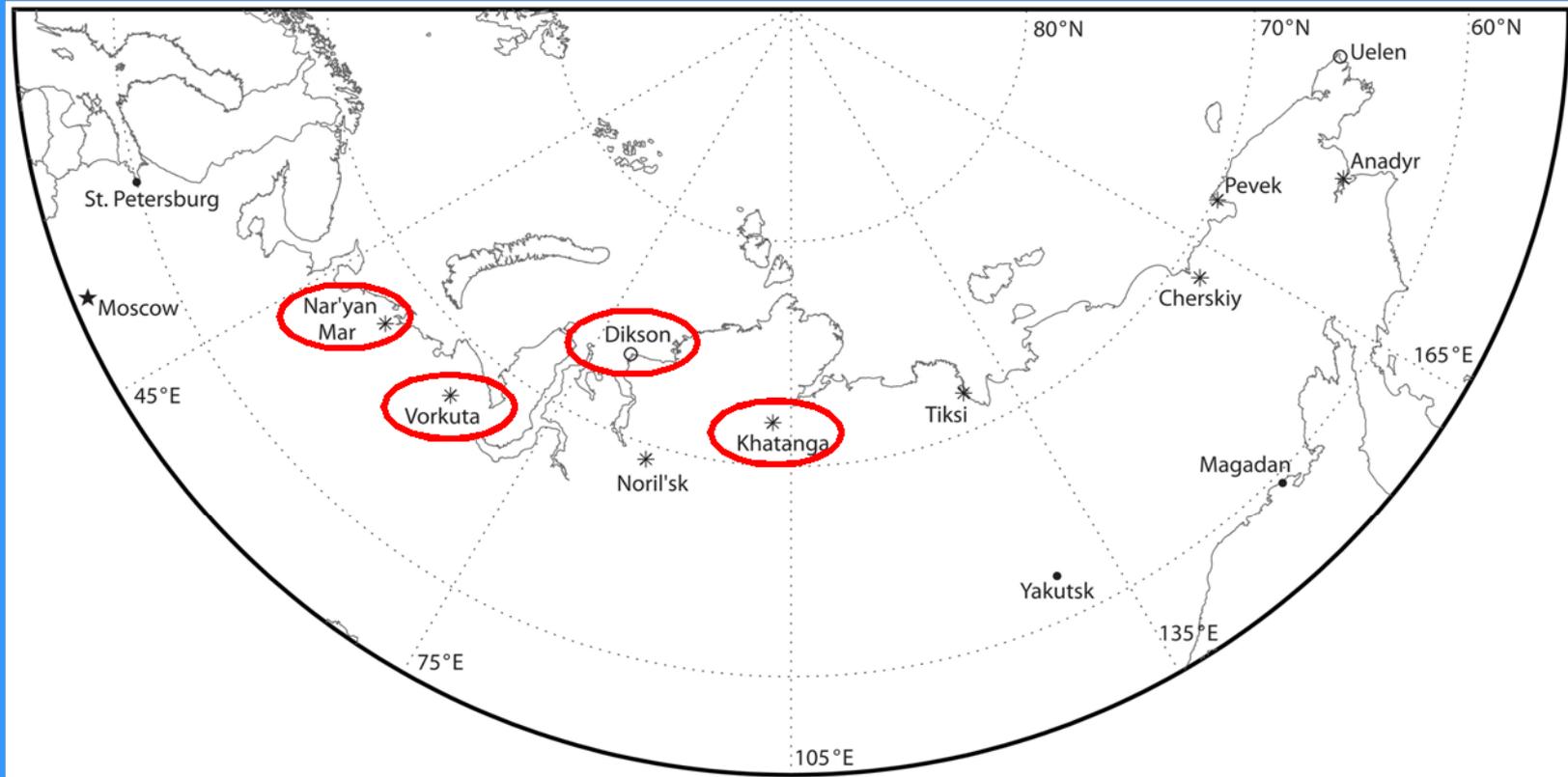
Goals/Issues suggested by the analysis of the 2007 data set

- Are there seasonal differences in the source strengths?
- Are there other LAA chemical components besides black carbon. What are their sources?
- Can the various data sets available (e.g., 2007, 2008, 2009) be combined in a single large PMF analysis

2008 Data Set For Receptor Analysis

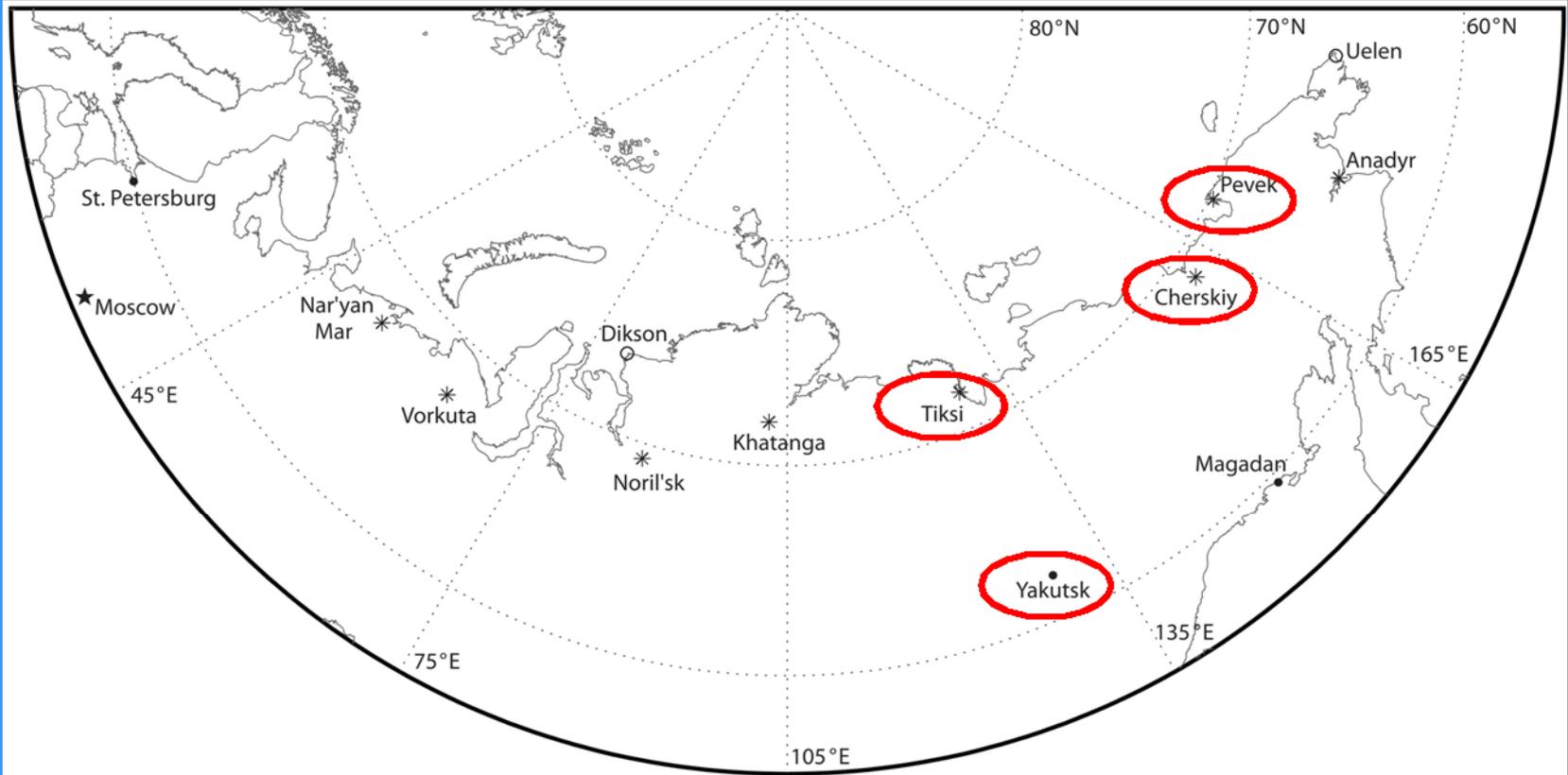
- 42 samples from Eastern Siberia including 4 depth profiles
- 15 samples from Greenland in one depth profile
- 4 surface sample from the North Pole
- Note: samples gathered in March-May, 2008 for Russian data, in July for Greenland profile and in April for the North Pole samples.

Previous sampling locations



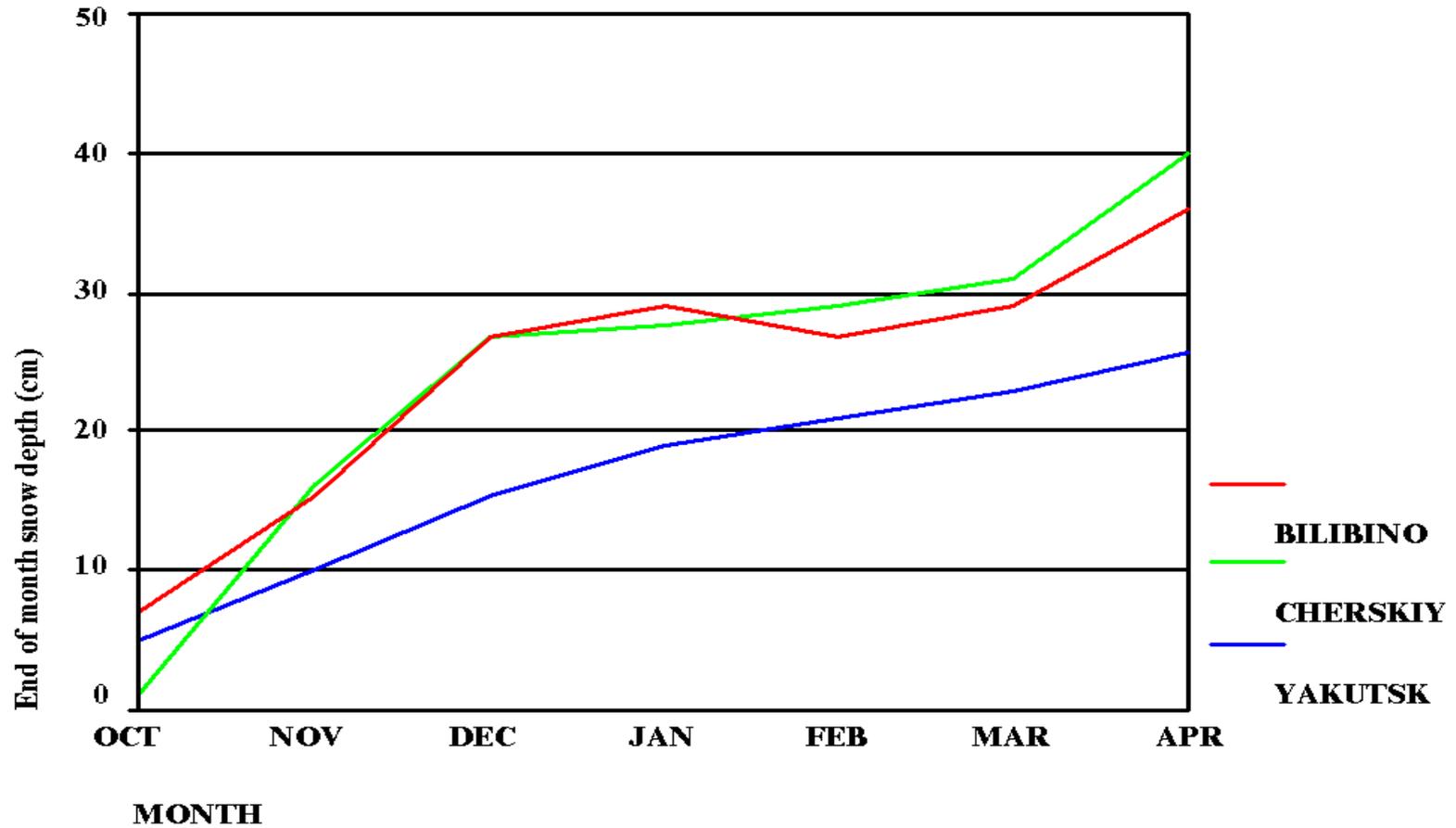
March-May 2007:
Western Russia

Sampling locations for 2008

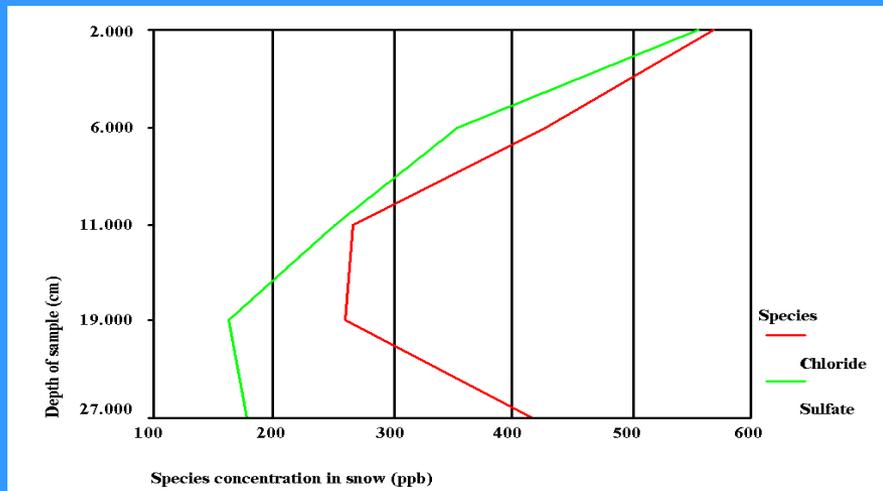
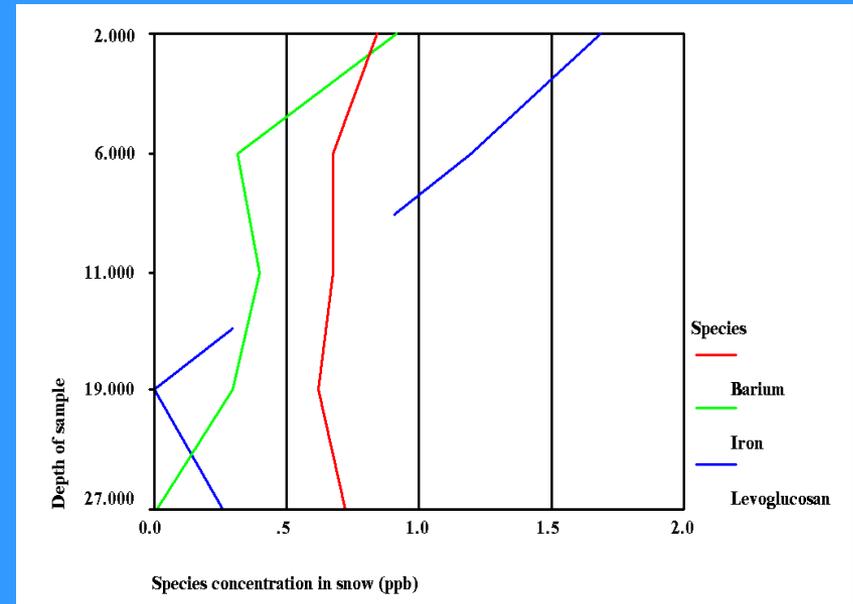
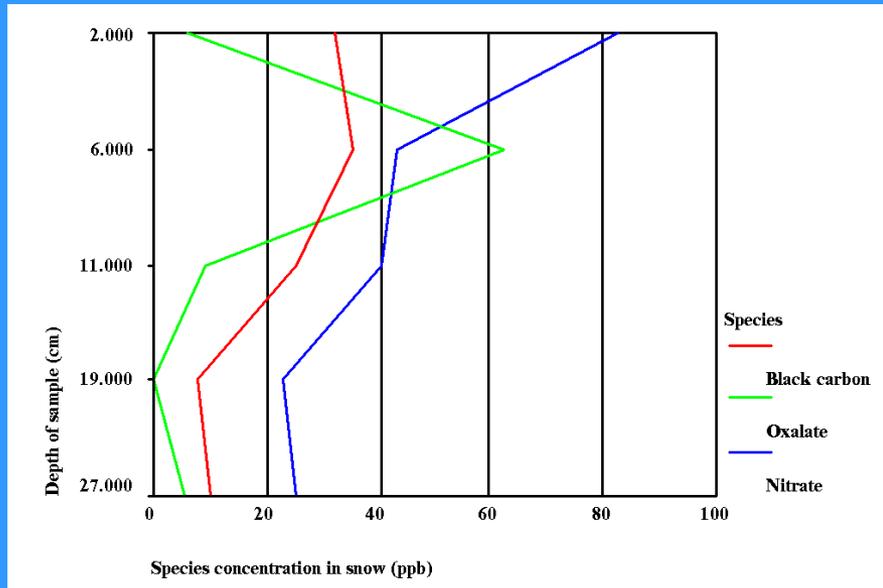


March-May 2008:
Eastern Russia

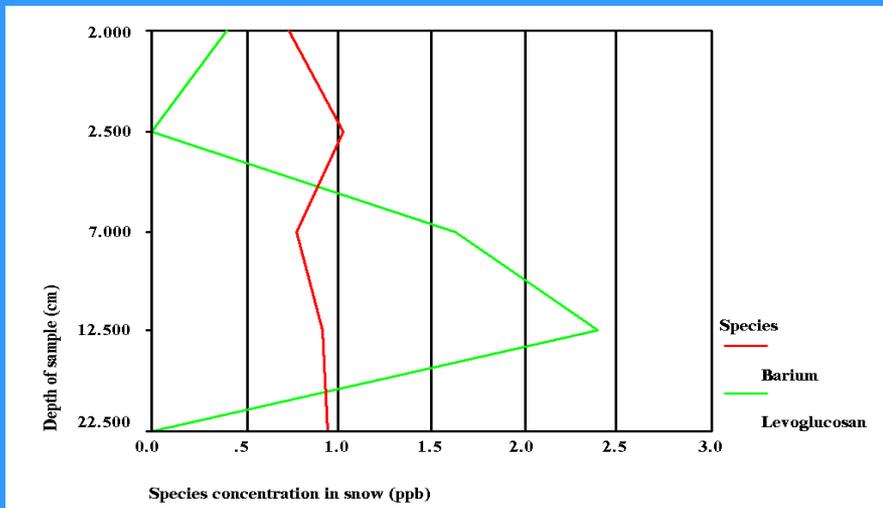
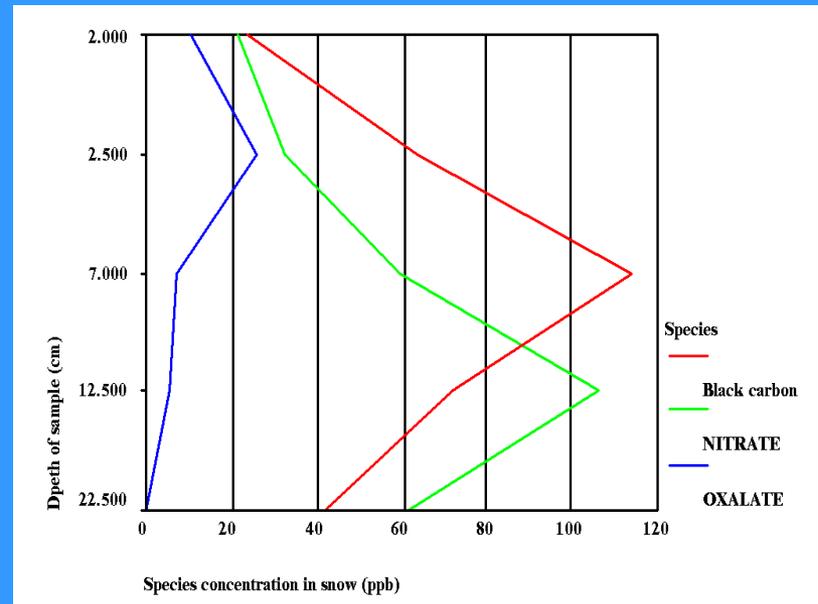
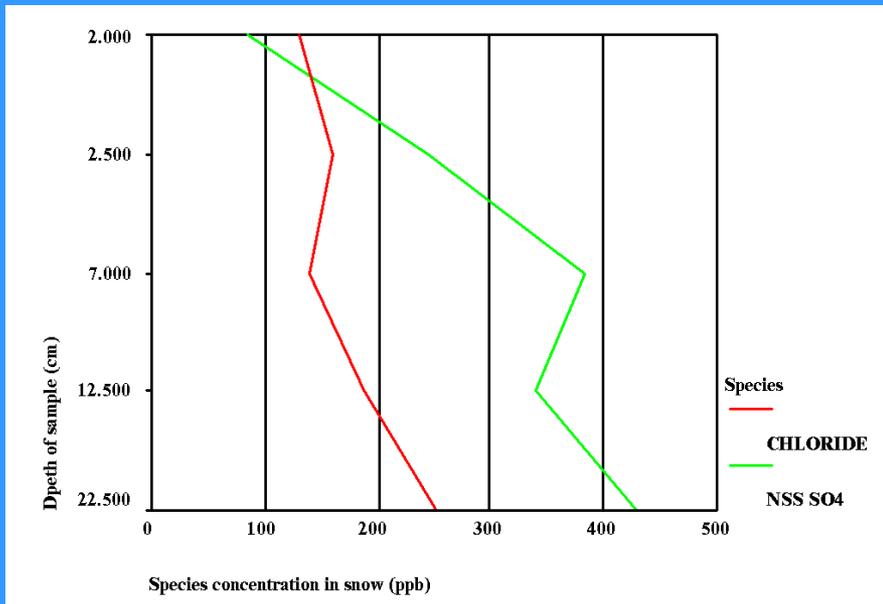
Snow depth time series: East Siberia



Chemical depth profiles: Cherskiy, 2008



Chemical depth profiles: Bilibino, 2008

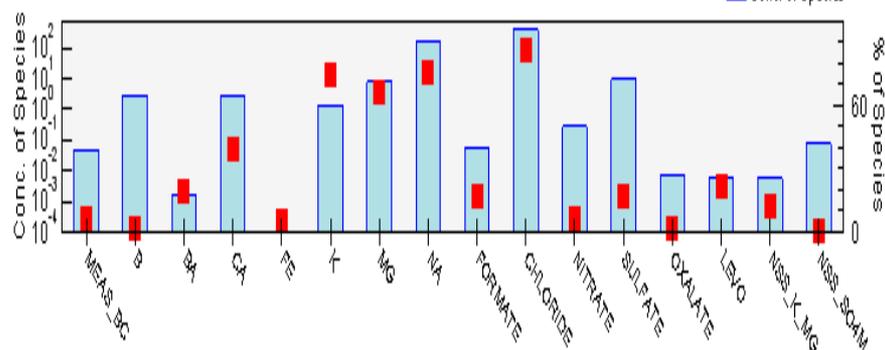


PMF factors derived from the 2008 data set

Fac. no. 1: marine

Factor Profile

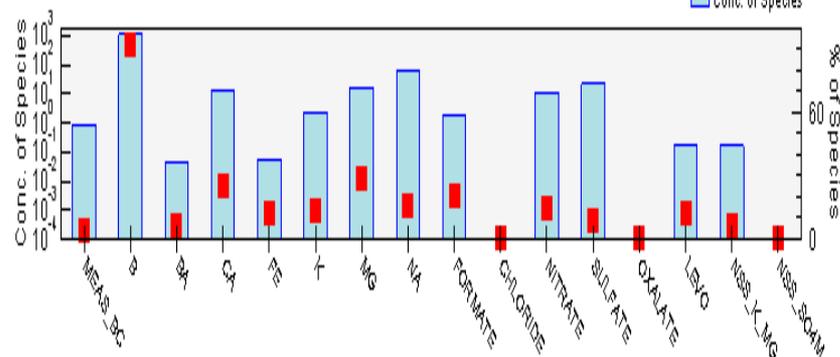
Legend: ■ % of Species
■ Conc. of Species



Fac. no. 2: marine?

Factor Profile

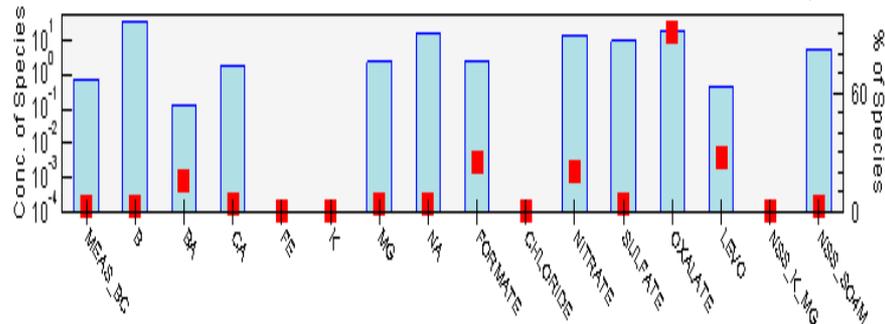
Legend: ■ % of Species
■ Conc. of Species



Fac. no. 3: secondary?

Factor Profile

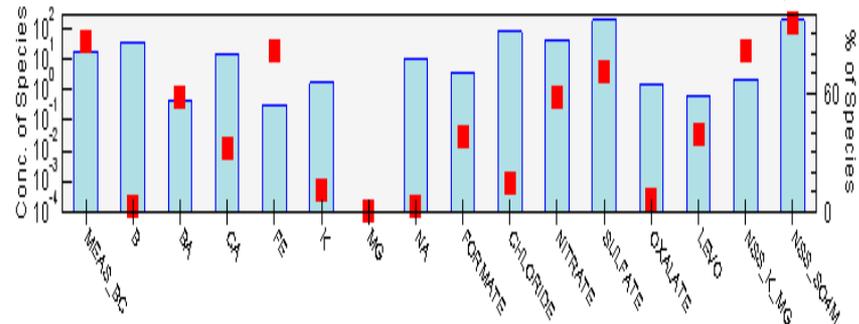
Legend: ■ % of Species
■ Conc. of Species



Fac. no 4: biomass/poll..

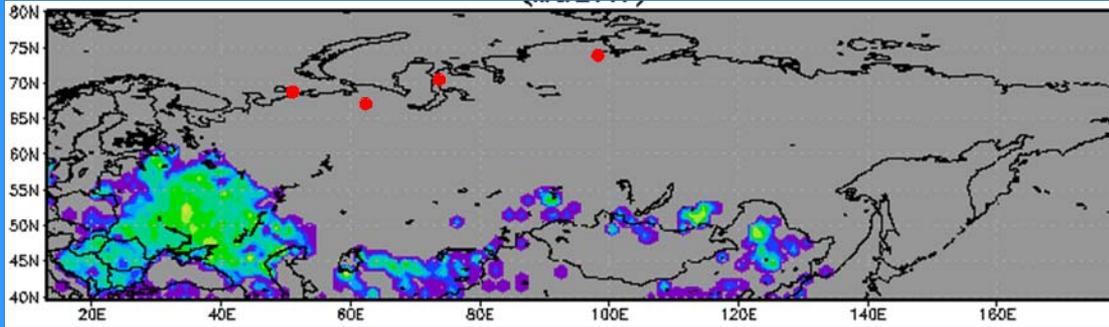
Factor Profile

Legend: ■ % of Species
■ Conc. of Species

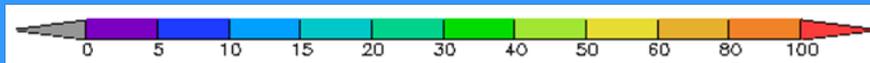
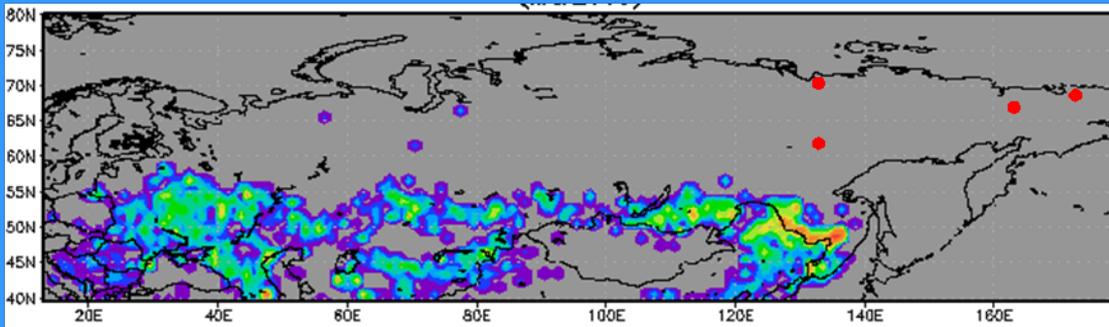


Fires in Russia, Spring 2007 vs. 2008

March, 2007



March, 2008

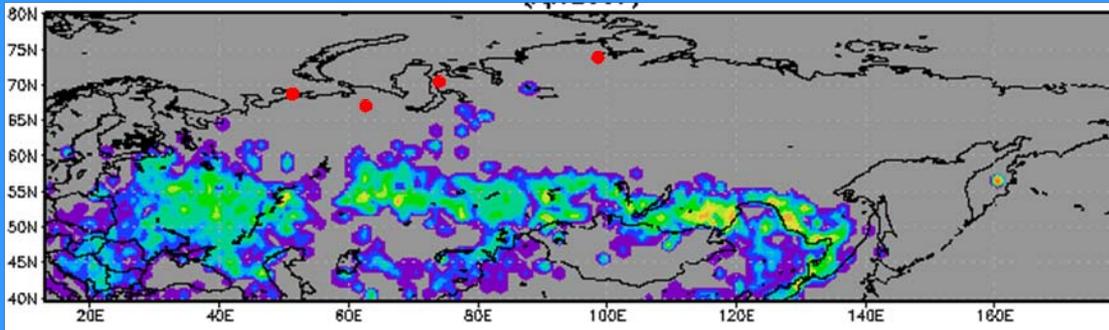


*fire radiative power (MW)
from MODIS*

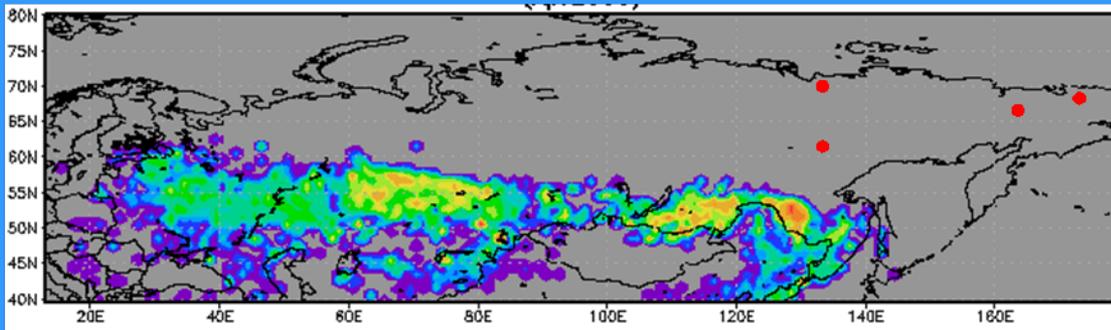
Credit: Giovanni online data system, developed and maintained by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC)

Fires in Russia, Spring 2007 vs. 2008

April, 2007



April, 2008



*fire radiative power (MW)
from MODIS*

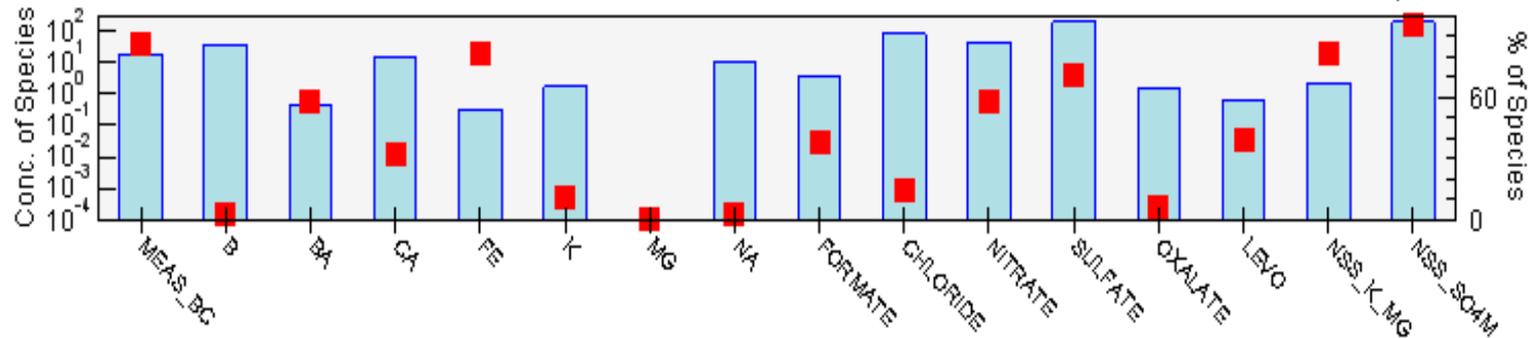
Credit: Giovanni online data system, developed and maintained by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC)

Comparison of PMF factors for all data and depth only data

Biomass/poll. Factor: all data

Factor Profile

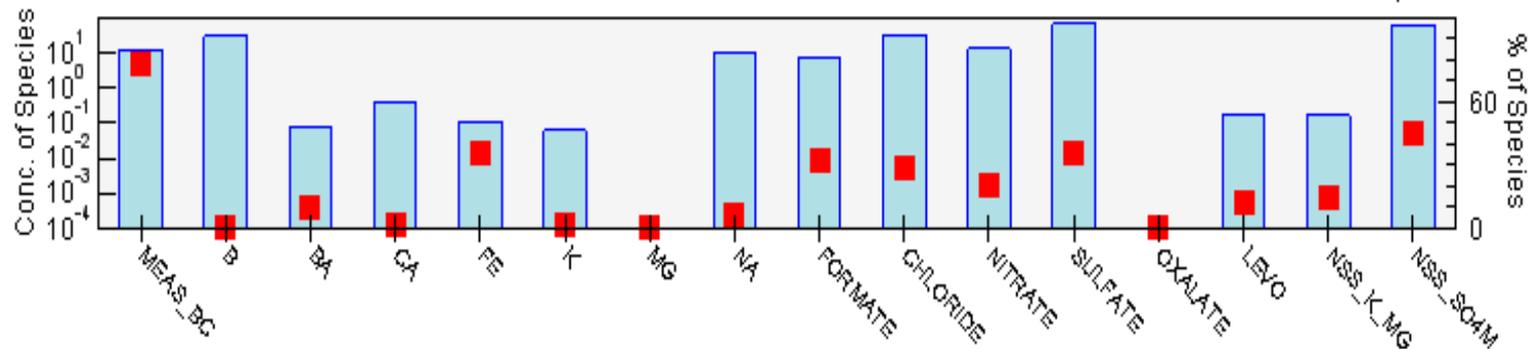
Legend: ■ % of Species
 □ Conc. of Species



Pollution factor: depth data

Factor Profile

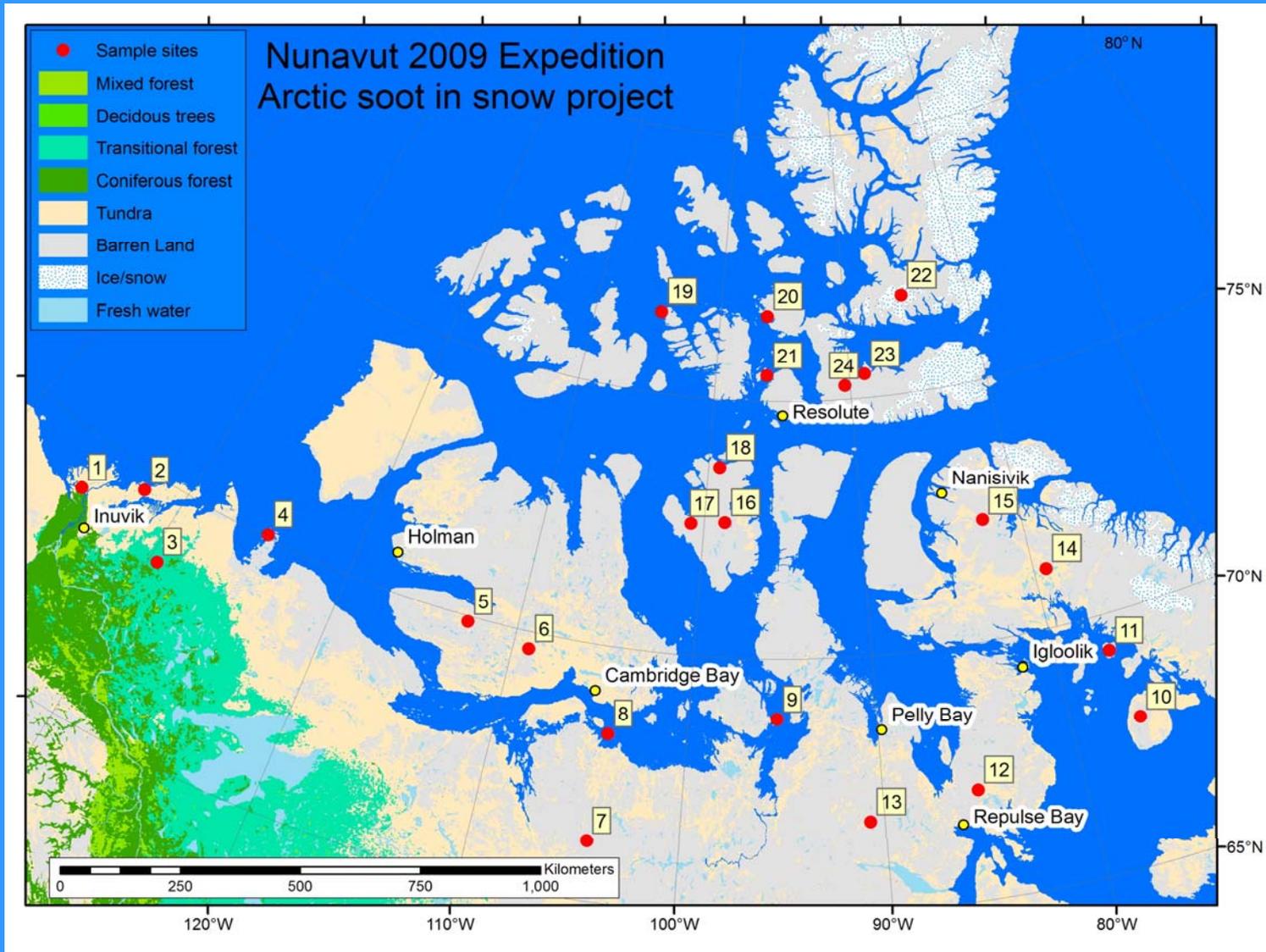
Legend: ■ % of Species
 □ Conc. of Species



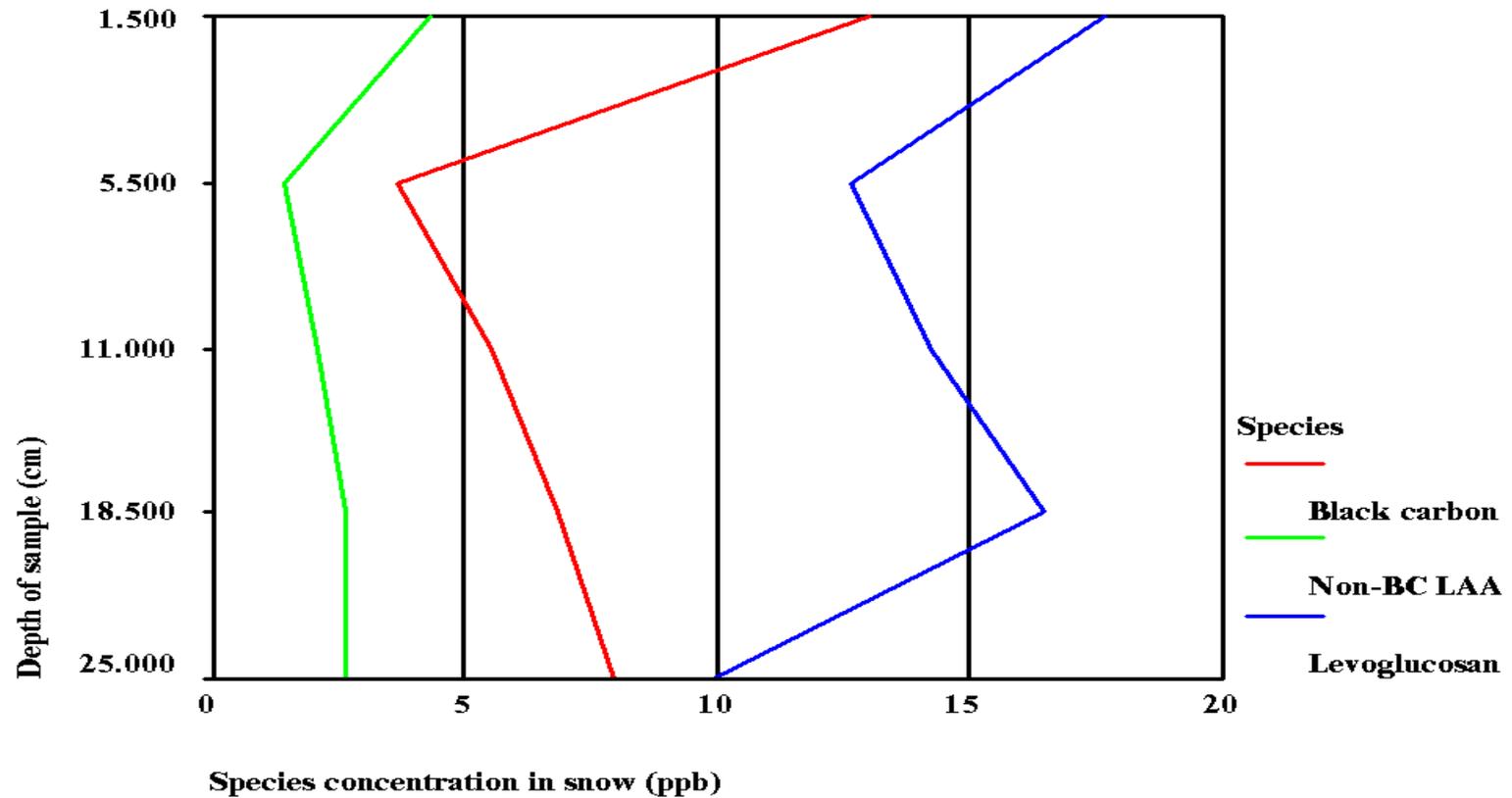
2009 Data set for receptor modeling (Canadian Arctic)

- 132 total samples
- 24 locations with a depth profile at each site
- Note samples were gathered in April-May

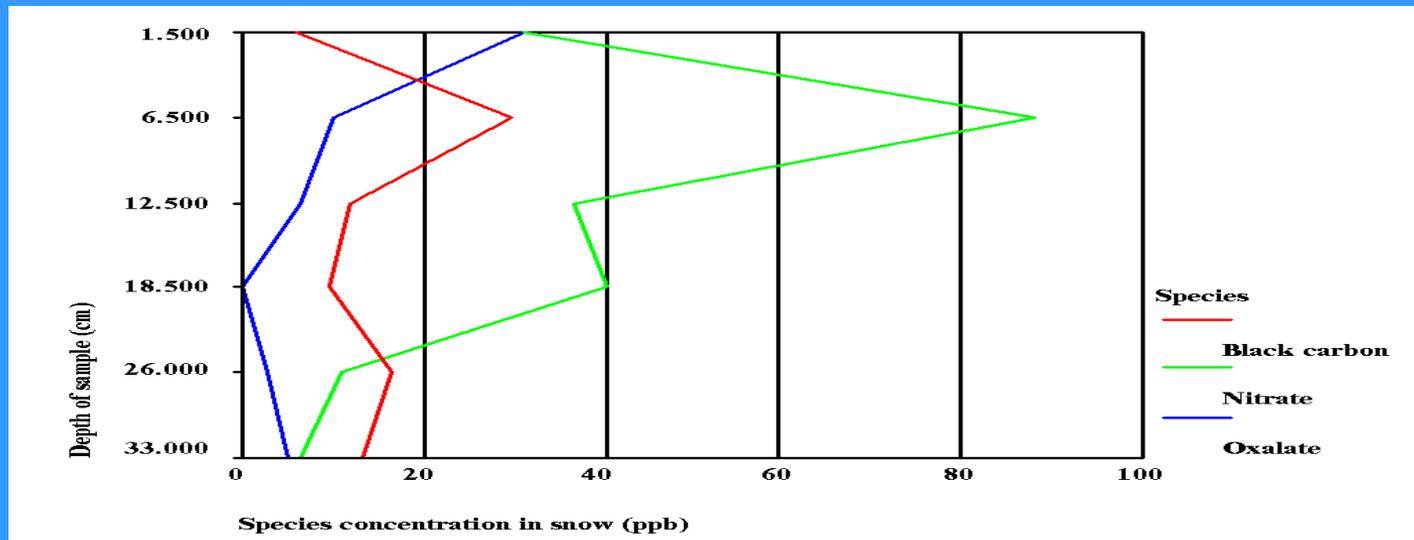
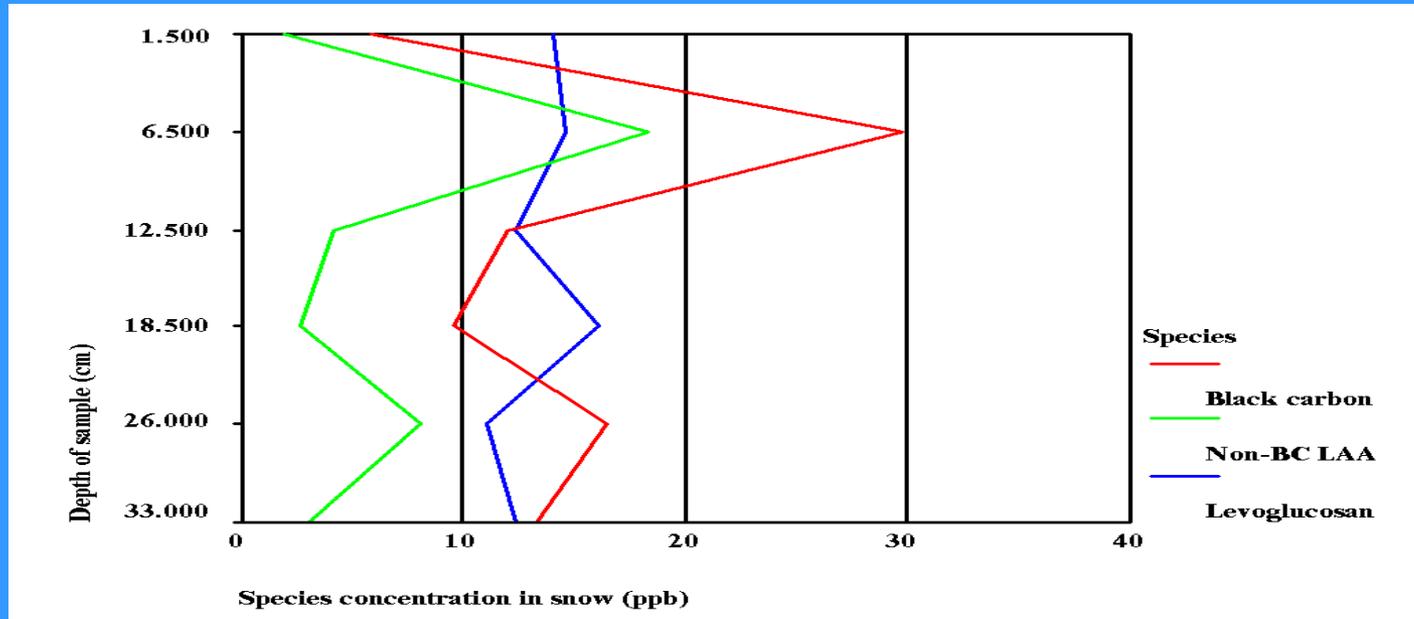
Sampling locations: 2009



Canadian chemical depth profile: site 7



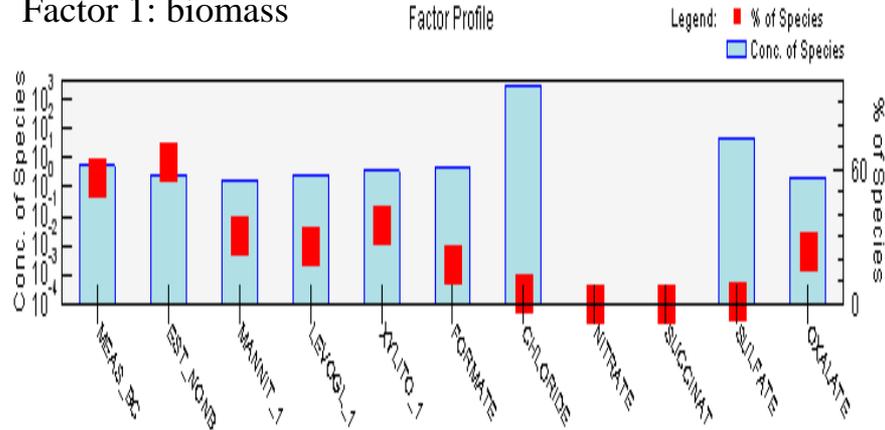
Canadian chemical depth profile: site 18



PMF factors derived from 2009 data set: preliminary analysis with limited analytes

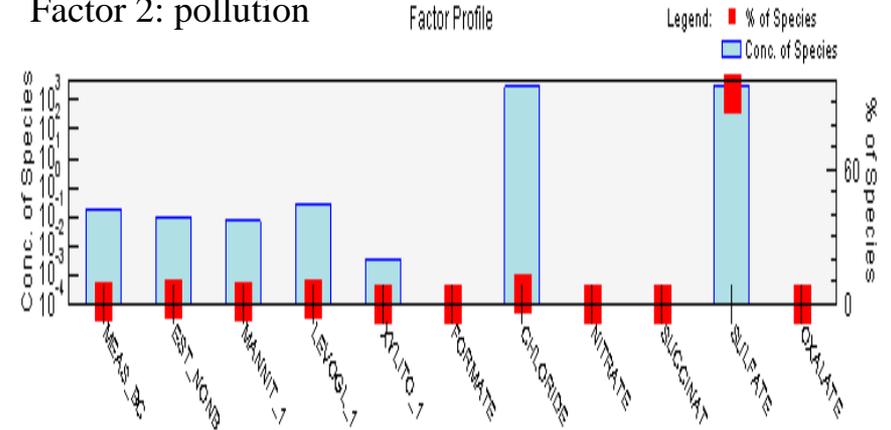
Factor 1: biomass

Factor Profile



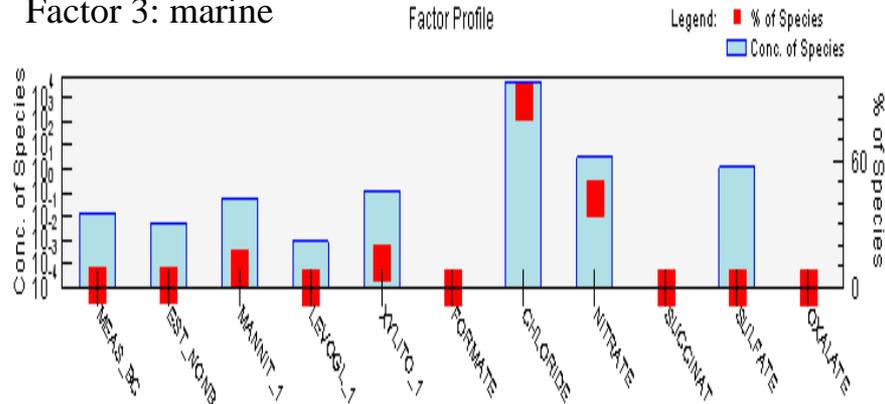
Factor 2: pollution

Factor Profile



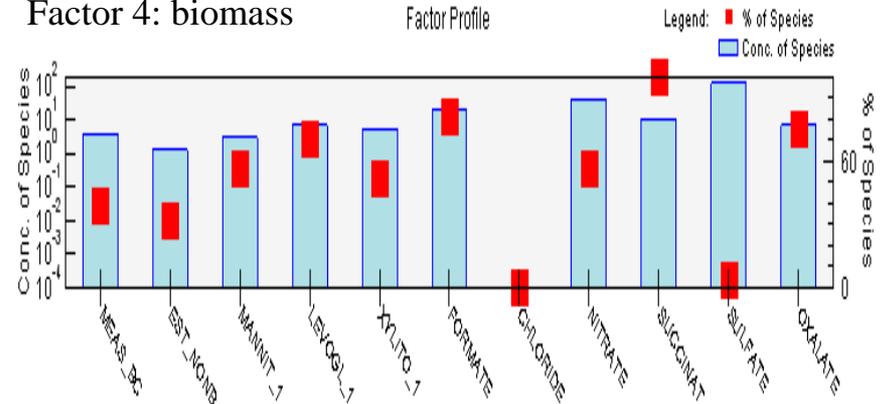
Factor 3: marine

Factor Profile

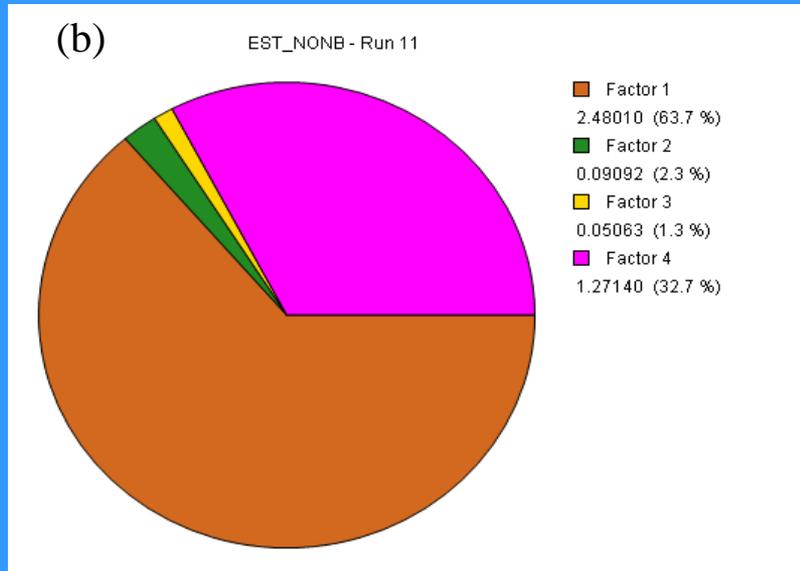
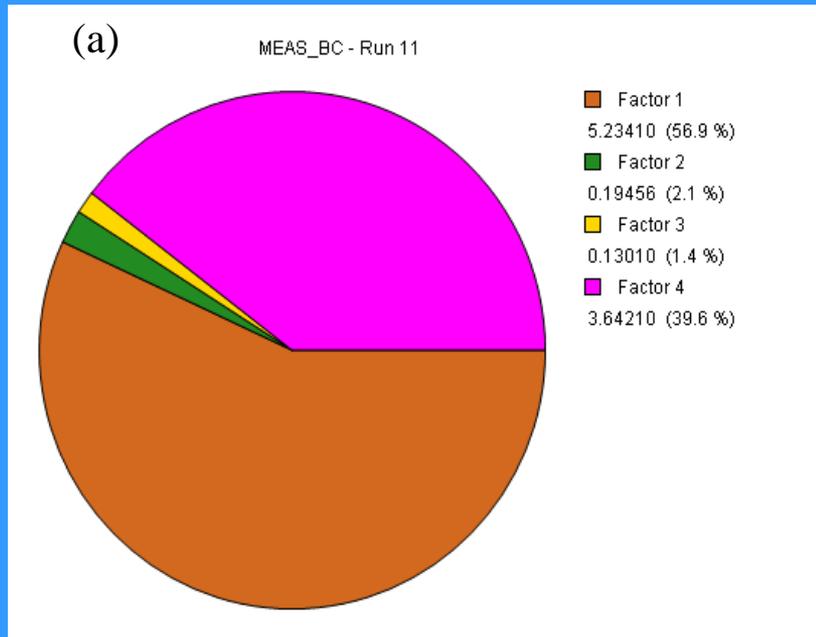


Factor 4: biomass

Factor Profile

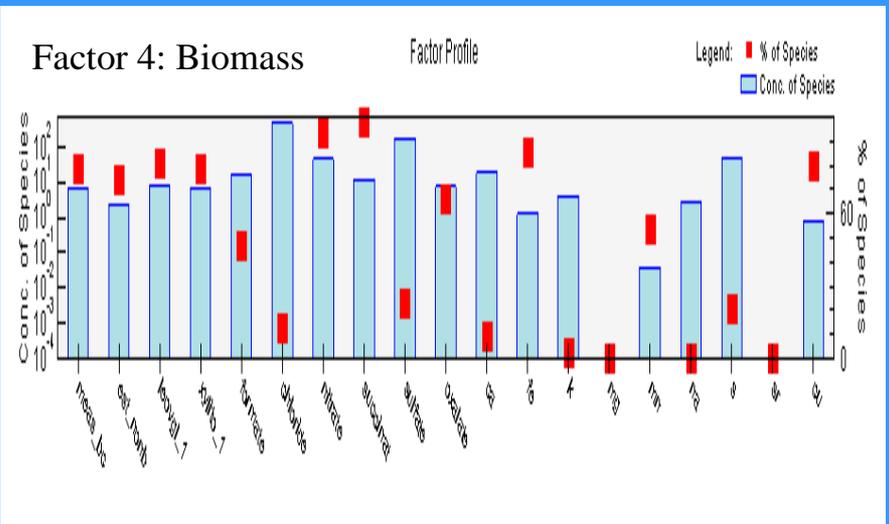
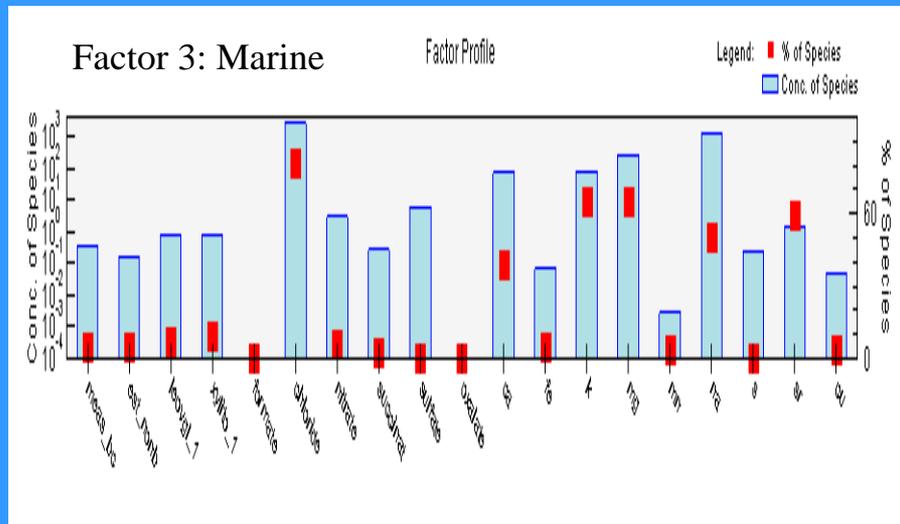
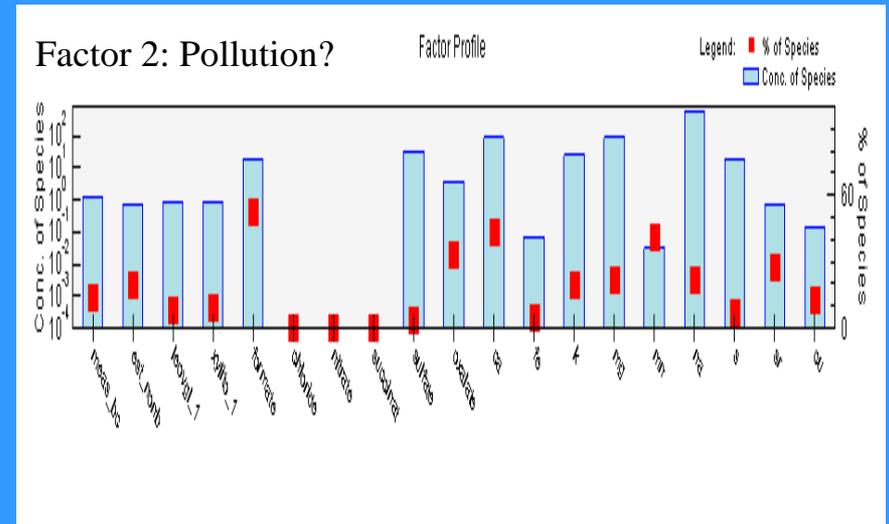
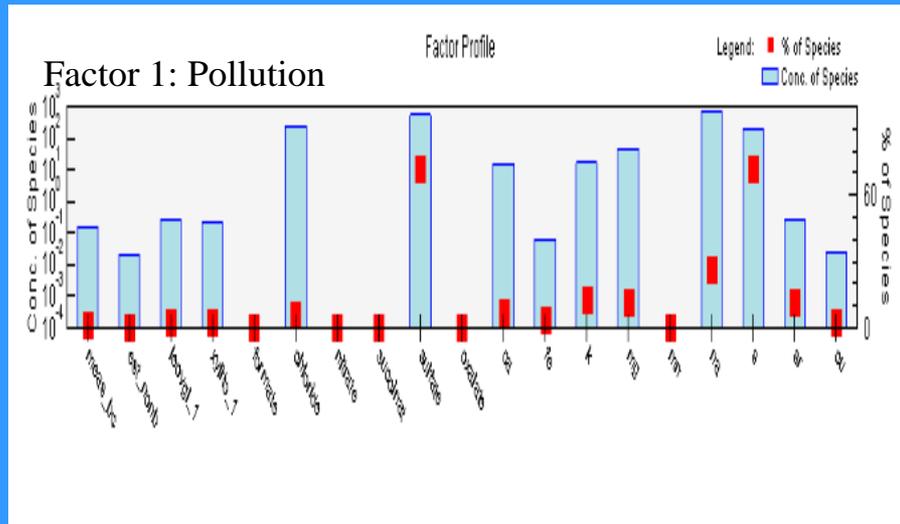


Factor allocation of Canadian LAA mass (limited analytes)

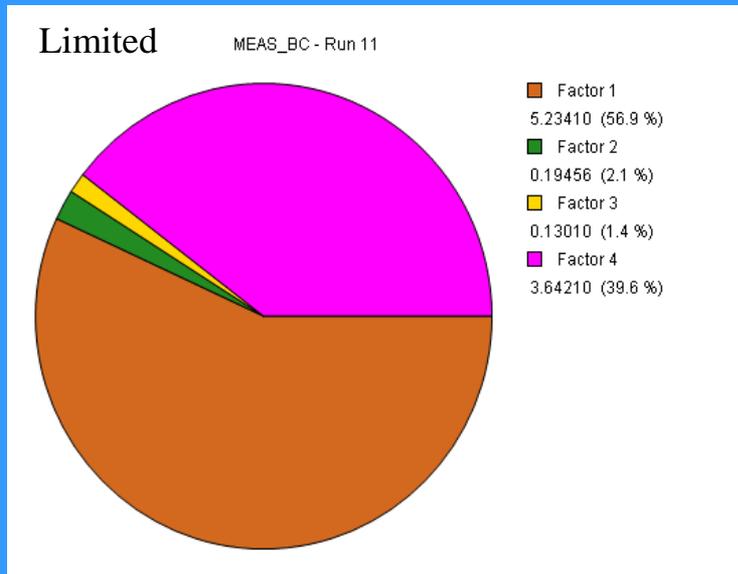


- Panel (a) is the allocation of black carbon mass
- Panel (b) is the allocation of non-black carbon absorbing aerosol
- Factor 1 = biomass
- Factor 2 = pollution
- Factor 3 = marine
- Factor 4 = biomass
- Note that the factors and factor loadings do not qualitatively change with depth
- Note: NOT a source attribution

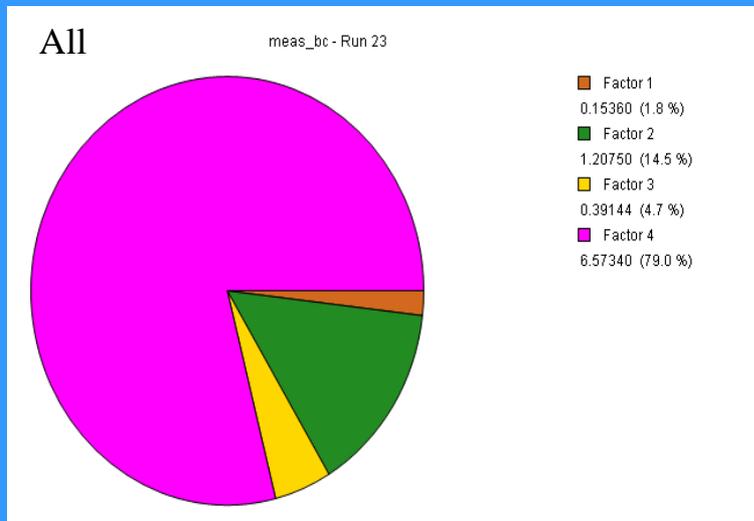
PMF Factors Derived From Extended Analyte Suite



Factor allocation of Canadian LAA mass (all analytes)



- Factor allocation for limited and all analytes
- Limited Key
 - Factor 1= biomass
 - Factor 2 = pollution
 - Factor 3 = marine
 - Factor 4 = biomass



- All Key
 - Factor 1=pollution
 - Factor 2= pollution ?
 - Factor 3= marine
 - Factor 4= biomass

Source allocation of BC mass by depth



Conclusions based on the PRELIMINARY analysis

- For the 2008 data set (mostly East Siberian data), a biomass burning/pollution factor is the factor most heavily loaded by the LAA (resolution of the biomass and pollution is not good for the overall data set).
- Based on stratification of the PMF analysis of the 2008 data by depth (time of deposition), there is some seasonality to the factor allocation of LAA, with biomass burning more prominent in the spring, as expected.
- For the 2009 data set (Canadian Arctic), biomass burning is virtually the sole factor loaded by LAA (note that depth stratification showed no seasonality of the sources).
- Based on the 2009 data set, black carbon and non-black carbon LAA are loaded on the same factor(s). (Note this could be due to poor separation of the BC and Non-BC LAA.) This is NOT a source attribution (yet).

Future Work

- Develop methodology for alternate biomass tracers (e.g. vanillin) for 2008 and 2009 data sets.
- Analysis of additional samples from Svalbard (24), Alaska (20), Greenland (16) and the North Pole (10).
- Assessment of stationarity of sources over the 2007-2010 time frame. If feasible, combination of all data into a single PMF analysis.