National Oceanic and Atmospheric Administration

Regional Aerosol Properties: Shipboard Intensives and Long-term Measurements

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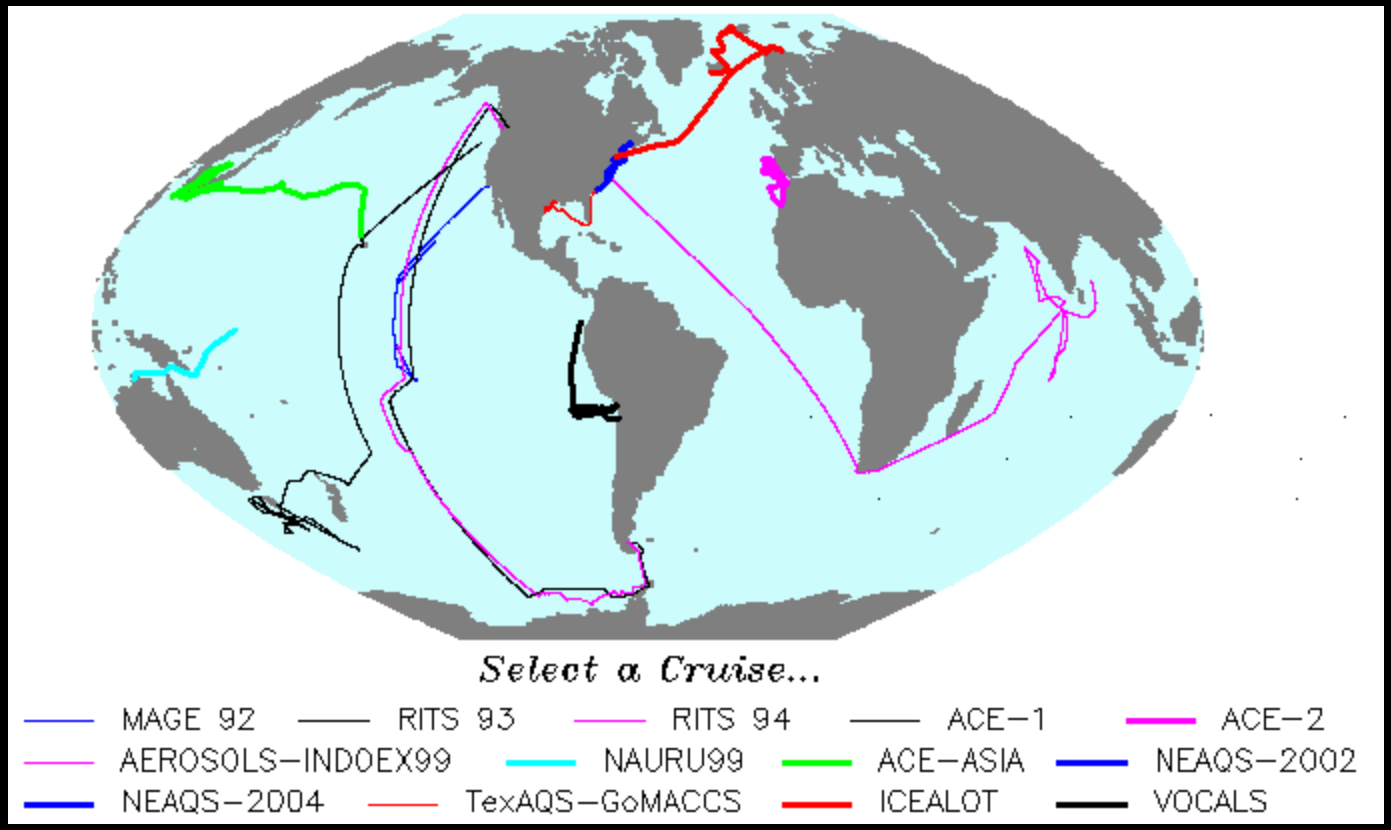
PMEL Atmospheric Chemistry Data Server: Shipboard Measurements

http://saga.pmel.noaa.gov/data/



Project/Cruise: ICEALOT 2008

ACTION

Plot Time or Space Series

Plot One Variable vs. Another

Download data file

View Parameter Info

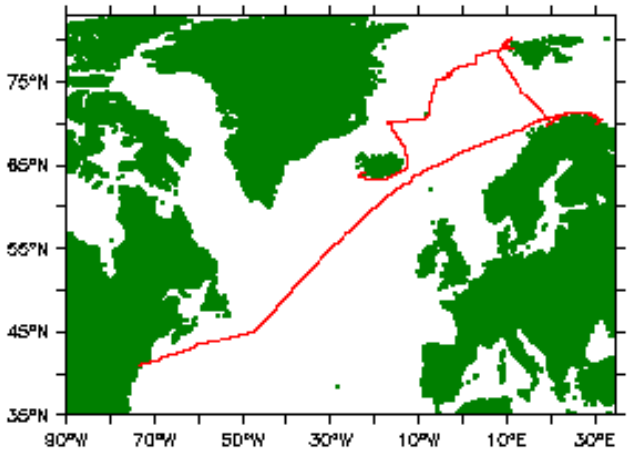
Plot Particle Size Distributions

Aerosol Chemistry Distributions

Plot Radiosonde Data

Go to Another Cruise

- **VESSEL: R/V Knorr**
- **DEPARTED: Woods Hole, Massachusetts on 19 March, 2008**
- **ARRIVED: Tromso, Norway on 12 April 2008**
- **DEPARTED: Tromso, Norway on 13 April 2008**
- **ARRIVED: Reykjavik, Iceland on 24 April 2008**
- **Link to more ICEALOT 2008 pages**



http://saga.pmel.noaa.gov/data/

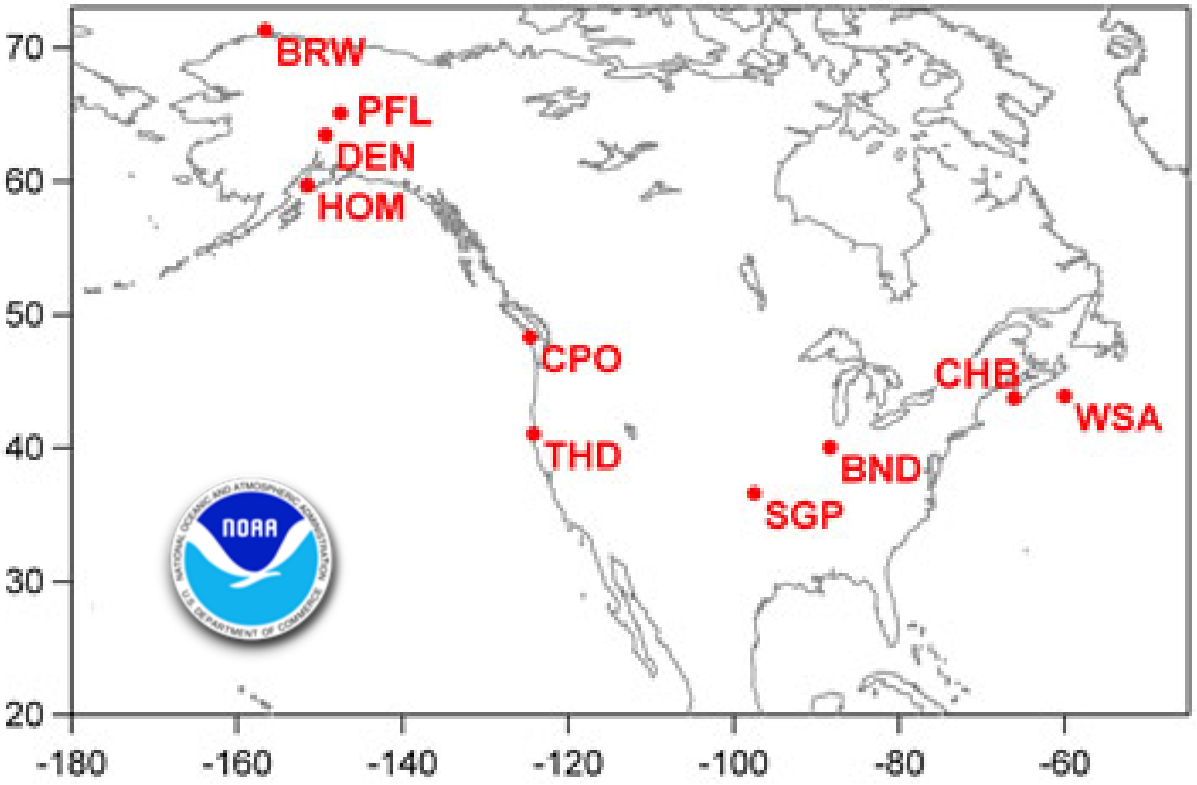
Shipboard Data Available for Download

http://saga.pmel.noaa.gov/data/

- Aerosol
    - Chemical composition
        - Impactors (2 or 7 stage) – inorganic ions, OC, EC, trace elements, mass
        - AMS – NR SO4, NO3, NH4, POM
    - Number concentration
    - Size distribution
    - Optical properties (sub – 1 um and sub – 10 um)
        - Scattering, backscattering, and absorption at 3 wavelengths
    - CCN concentration
    - Optical Depth
- Gas phase
    - DMS, SO2, O3
- Seawater
    - DMS
- Met parameters

PMEL Atmospheric Chemistry Data Server: Station Measurements

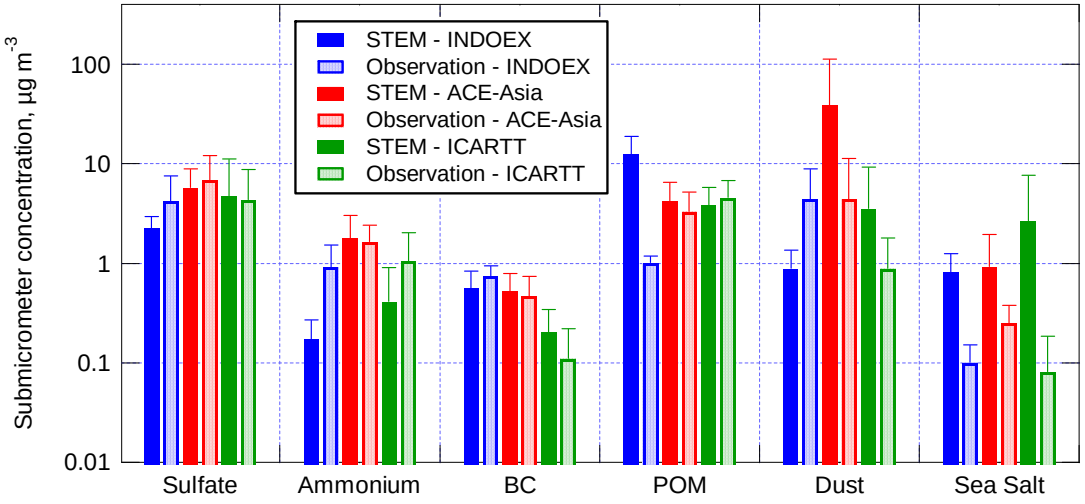
http://saga.pmel.noaa.gov/data/

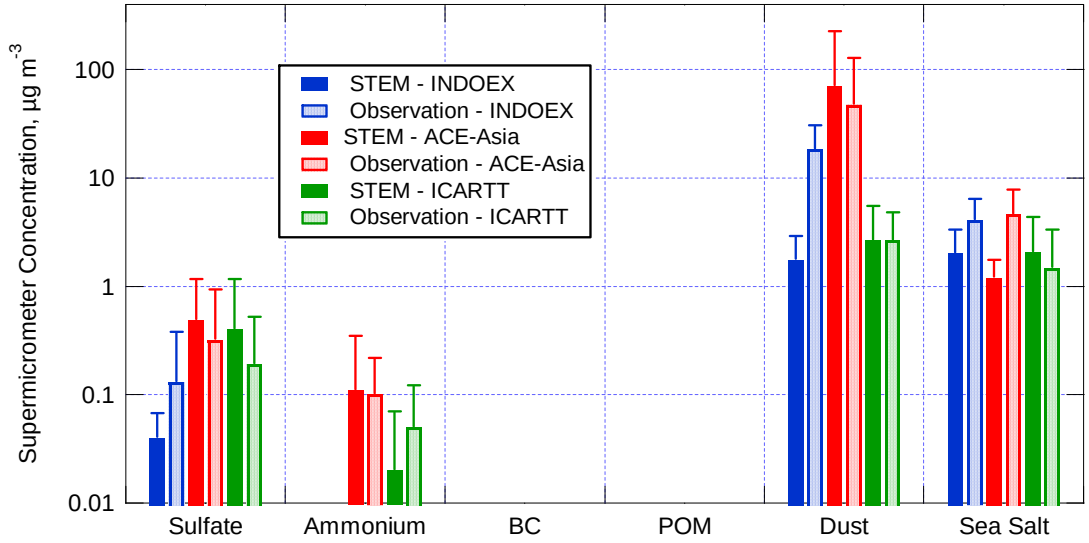


Aerosol composition

- sub-1 and sub-10 um
  - inorganic ions
  - gravimetric mass

Comparison of measured and modeled (STEM) concentrations from INDOEX, ACE-Asia, and ICARTT



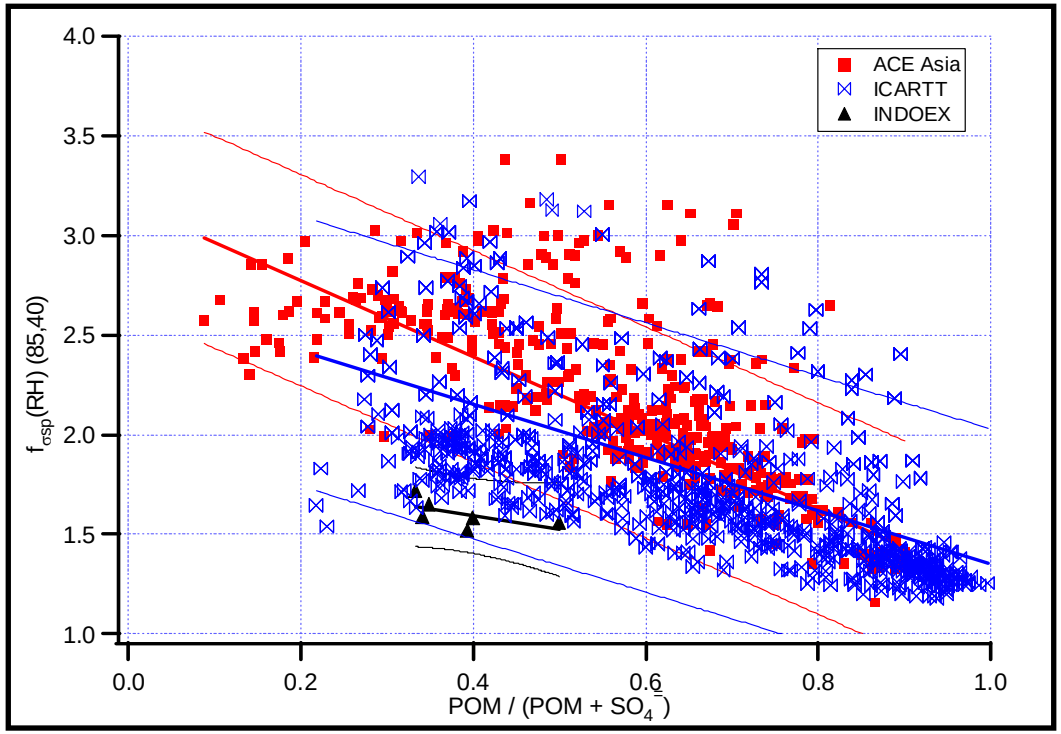


Model was driven by analyzed met data and sampled at the times and locations of the measurements every 30 min along the cruise track.

- Best agreement was found for submicron SO4 due to accuracy in emissions, chemical conversion, and removal.
- Underestimation of supermicron sea salt most likely due to errors in emissions.

Bates et al., ACP, 2006

Use of field measurements to parameterize the impact of particulate organic matter on the relative humidity dependence of light scattering



$$\gamma_S = \ln\left(f\sigma_{sp}\left(RH, RH_{ref} \right)\right) \Big/ \ln\left(\frac{100 - RH_{ref}}{100 - RH} \right)$$

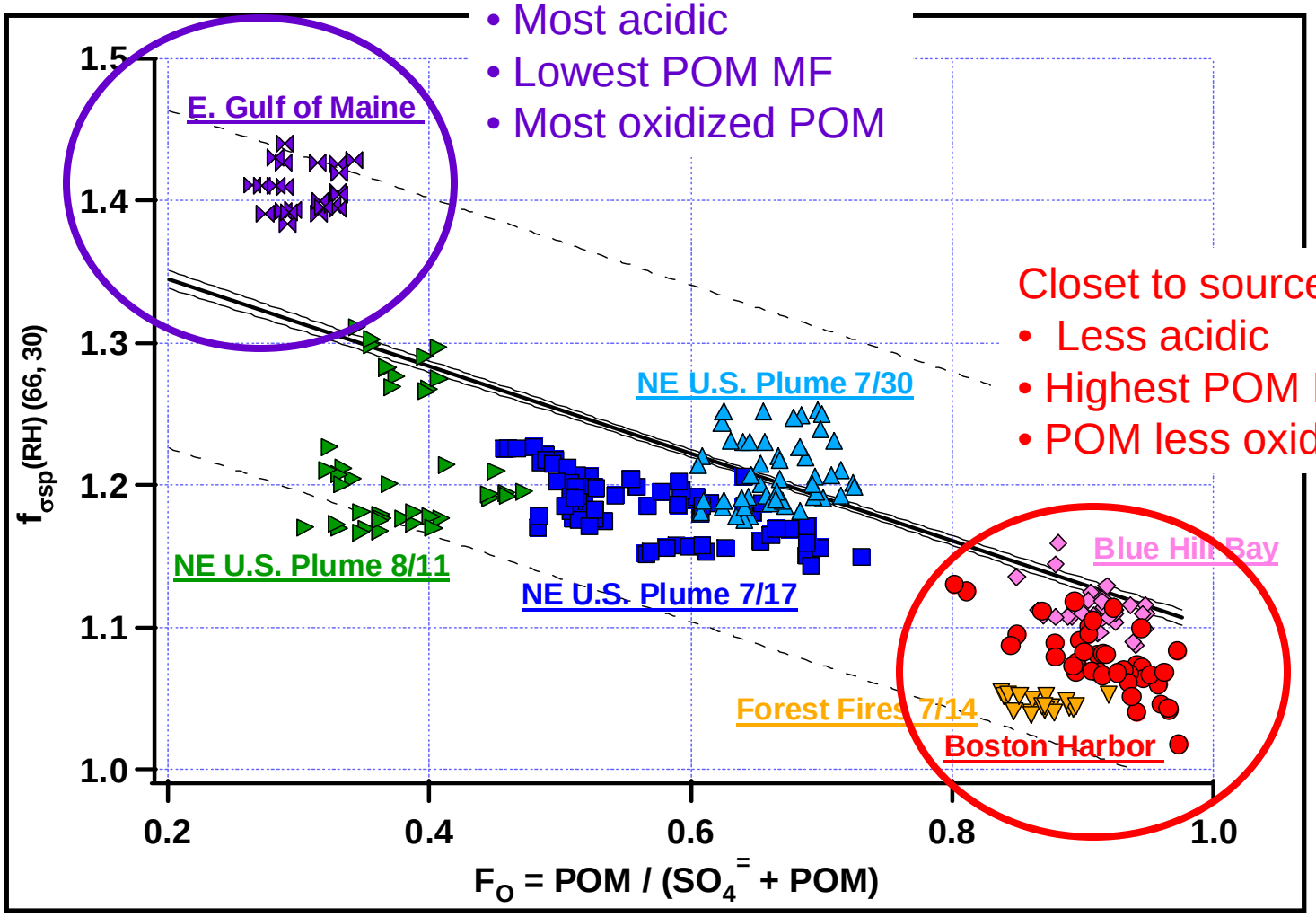
$$F_o = POM / \left(POM + SO4 \right)$$

$$\gamma_s = 0.9(\pm 0.003) - 0.6(\pm 0.01) F_O$$

Quinn et al., GRL, 2005.

Humidity Dependence of Light Extinction and Aerosol Age

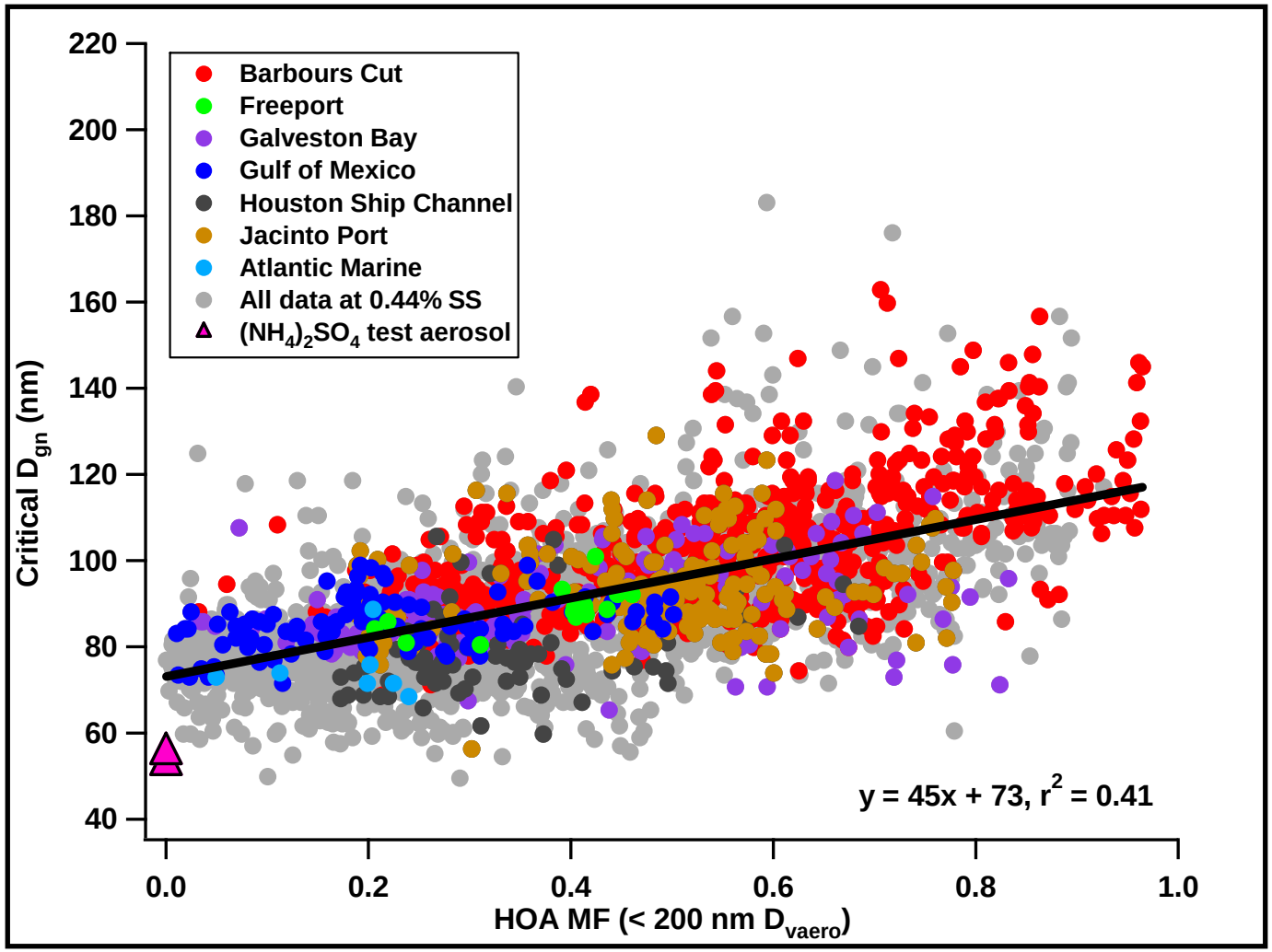
Furthest from source:
- Most acidic
- Lowest POM MF
- Most oxidized POM



Closet to source:
- Less acidic
- Highest POM MF
- POM less oxidized

Quinn et al., JGR. 2006

2006 TexAQS: Effect of Organics on CCN Activation



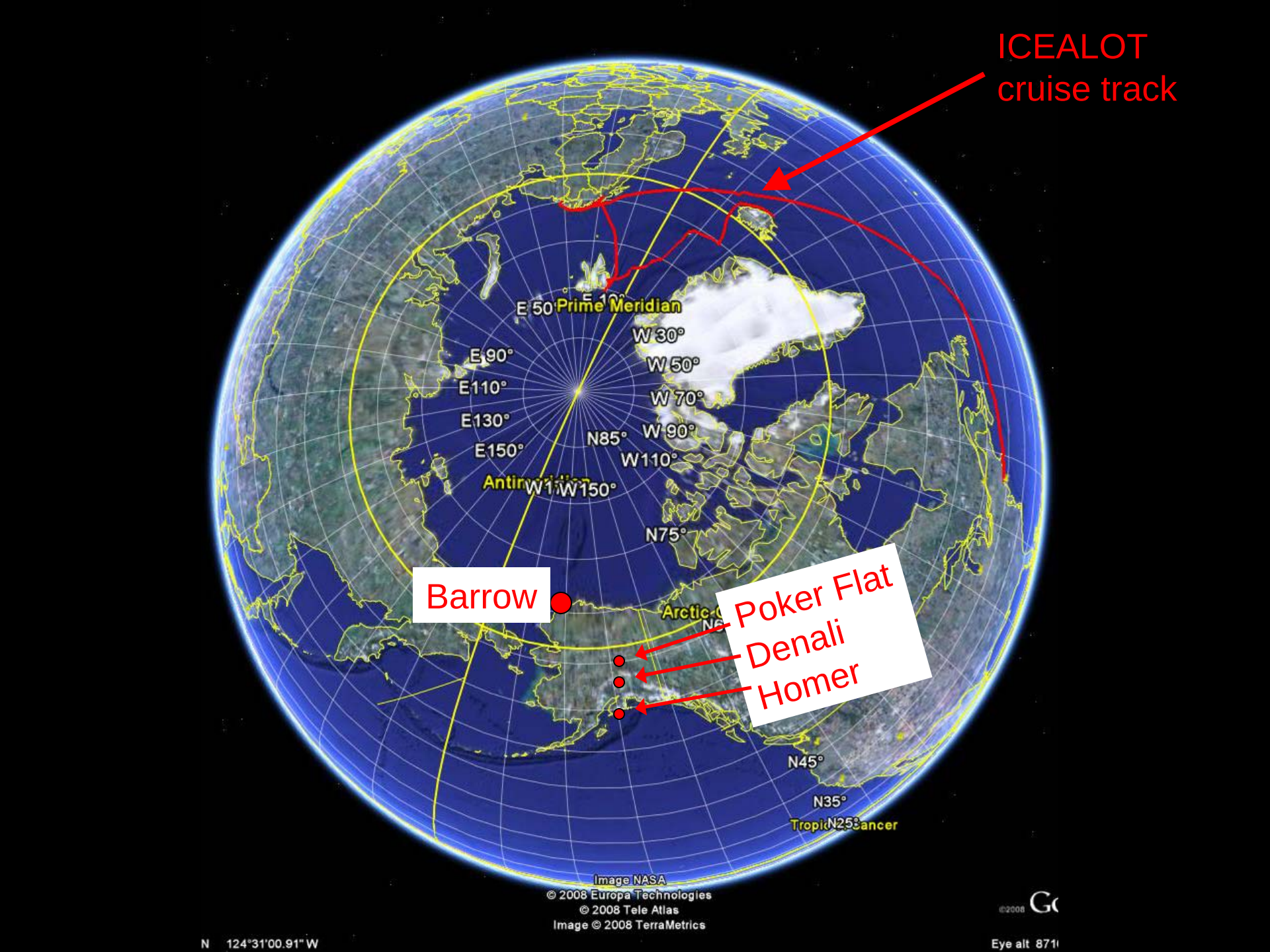
Increasing mass fraction of HOA leads to an increase in the critical diameter for particle activation

Quinn et al., ACP, 2008

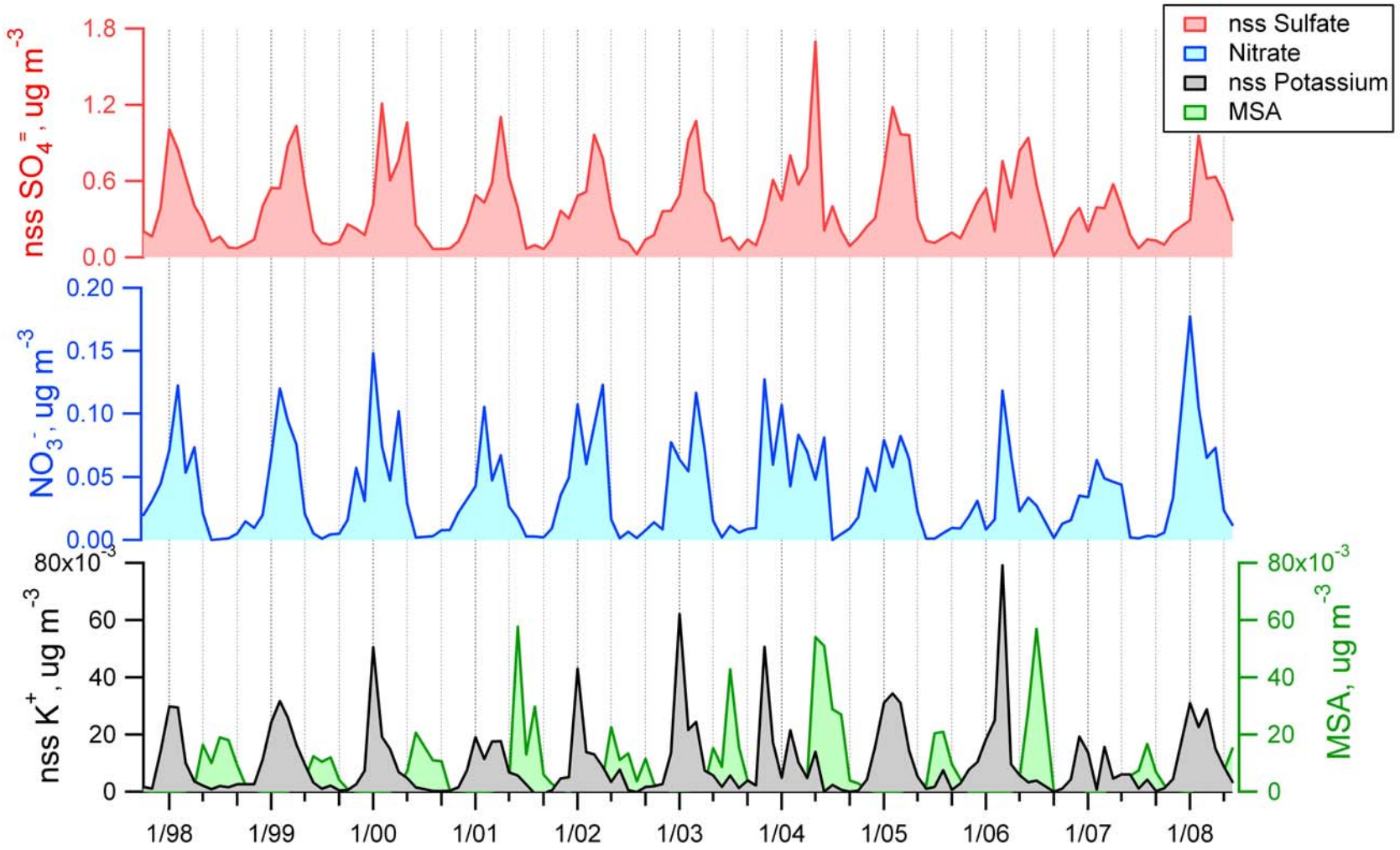
Decadal trends in aerosol chemical composition at Barrow, AK: 1976 - 2008

P.K. Quinn, T.S. Bates, and K. Schulz
NOAA PMEL

G. Shaw
University of Alaska, Fairbanks


ICEALOT
cruise track
E 50
Prime Meridian
W 30°
E 90°
W 50°
E110°
W 70°
E130°
N85°
W 90°
E150°
W110°
W150°
N75°
Barrow
Poker Flat
Denali
Homer
N45°
N35°
Tropic
Cancer
Image NASA
© 2008 Europa Technologies
© 2008 Tele Atlas
Image © 2008 TerraMetrics
N 124°31'00.91" W
Eye alt 871

Seasonality of Aerosol Composition at Barrow (1997 – 2008)



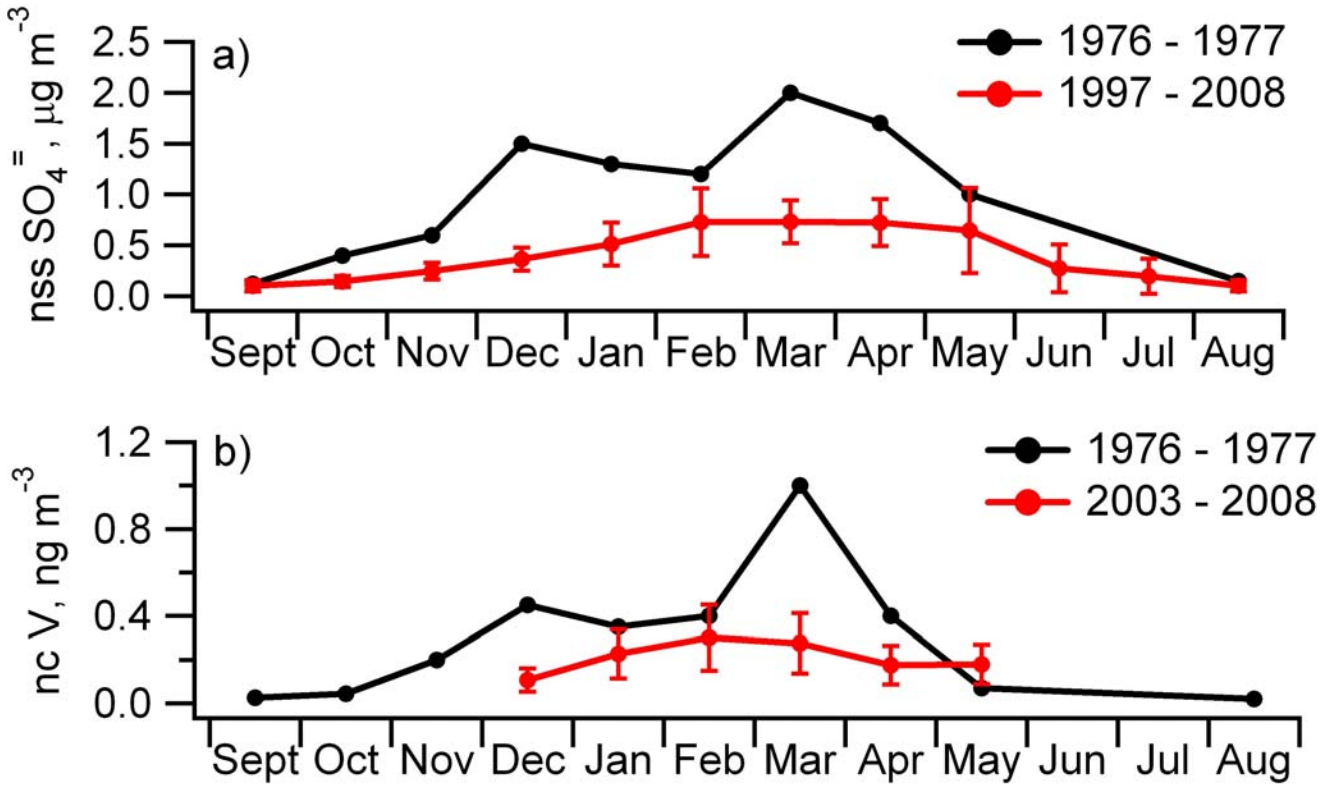
- nss $SO_4^=$, NO_3^-, nss K^+ → long range transport
- MSA → local biogenic production

Aerosol tracer species measured at Barrow during the past 30 years

Species	Winter/Spring Source	Summer Source	Measured 1976 - 1977?	Measured 1997 – 2008?
Non-seasalt $SO_4^=$ (nss $SO_4^=$)	Fossil fuel combustion	DMS (biogenic)	Yes	Yes
Non-crustal* Vanadium (nc V)	Mid-latitude combustion of heavy residual oil		Yes	Yes (2003 – 2008)
Non-crustal* Manganese (nc Mn)	Iron, steel, and ferro-alloy mfg, coal and oil combustion, mining		Yes	Yes (2003 – 2008)
Methanesulfonic acid (MSA)		DMS (biogenic)	No	Yes

* Excess V or Mn above that due to crustal rock

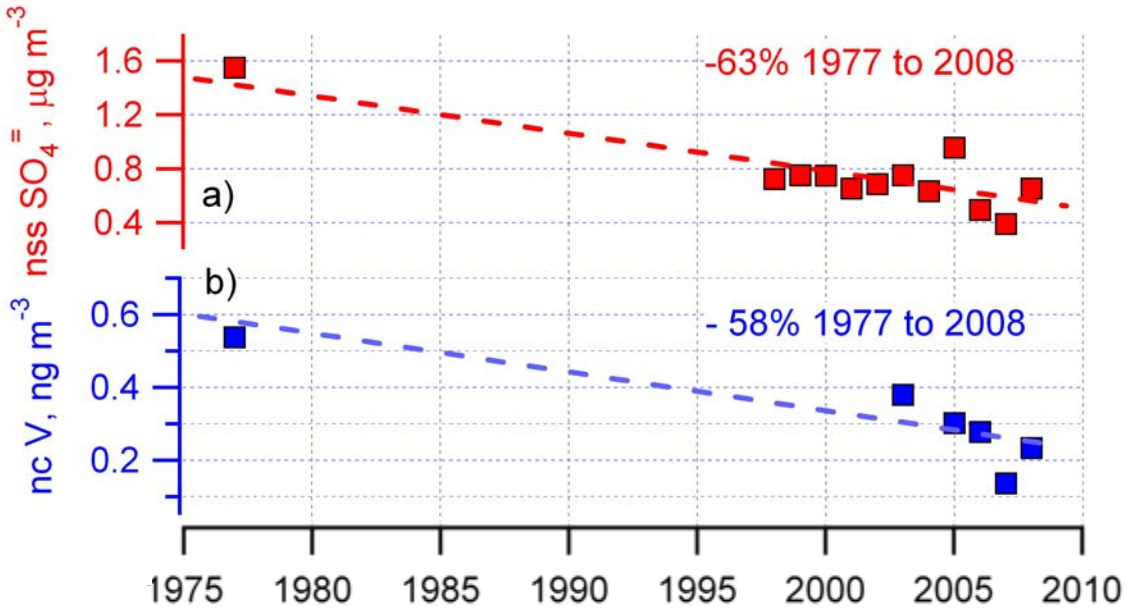
Comparison of monthly averaged values of nss $SO_4^=$ and nc V 1976 – 1977 vs. 1997 - 2008



Rahn & McCaffrey (1980)
Quinn et al. (2009)

- Similar seasonality
  - Broad winter/spring maximum – initial transport of $SO_4^=$produced in mid-latitudes followed by transport and oxidation of SO_2 enroute as light levels increase within the Arctic
- But…lower concentrations in later years

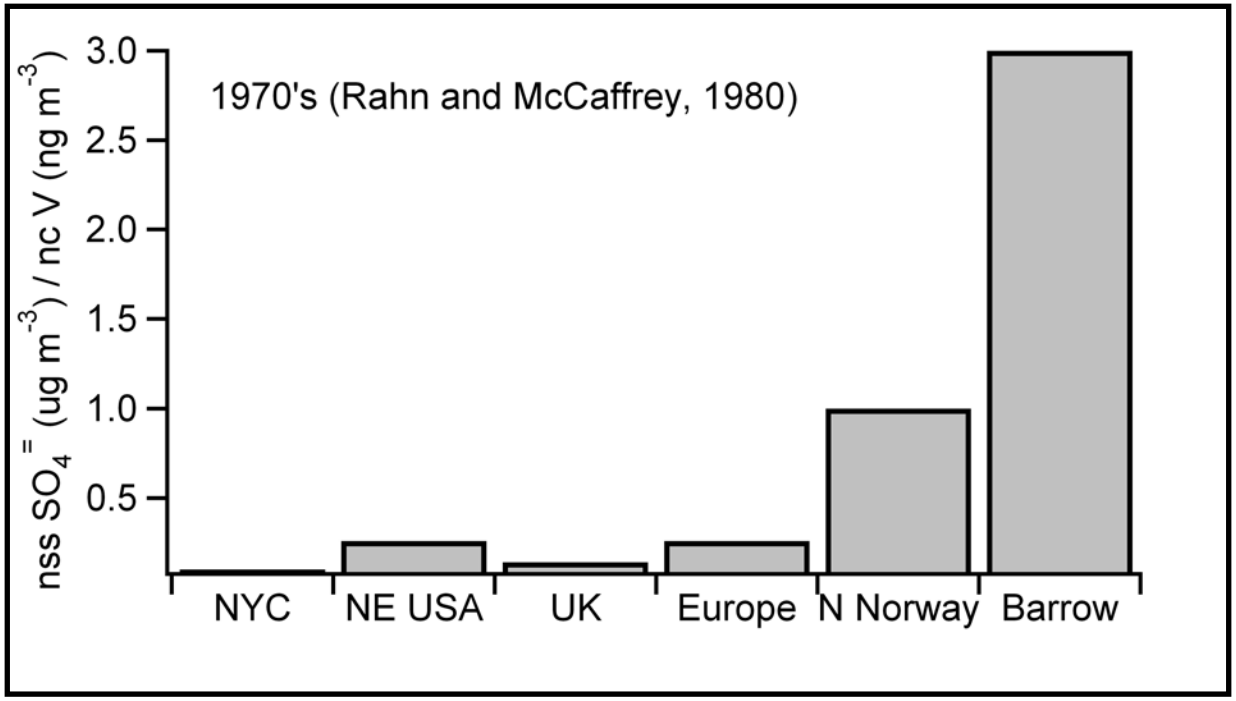
nss $SO_4^=$ and nc V averaged over the haze season (Jan – Apr): Then and Now



- Linear regression of concentrations averaged over the haze season reveals a 60% decrease over the past 30 years for both species

Haze season ratio of nss $SO_4^=$ to nc V as a tracer for mid-latitude pollution

nss $SO_4^=$ / nc V
secondary / primary component

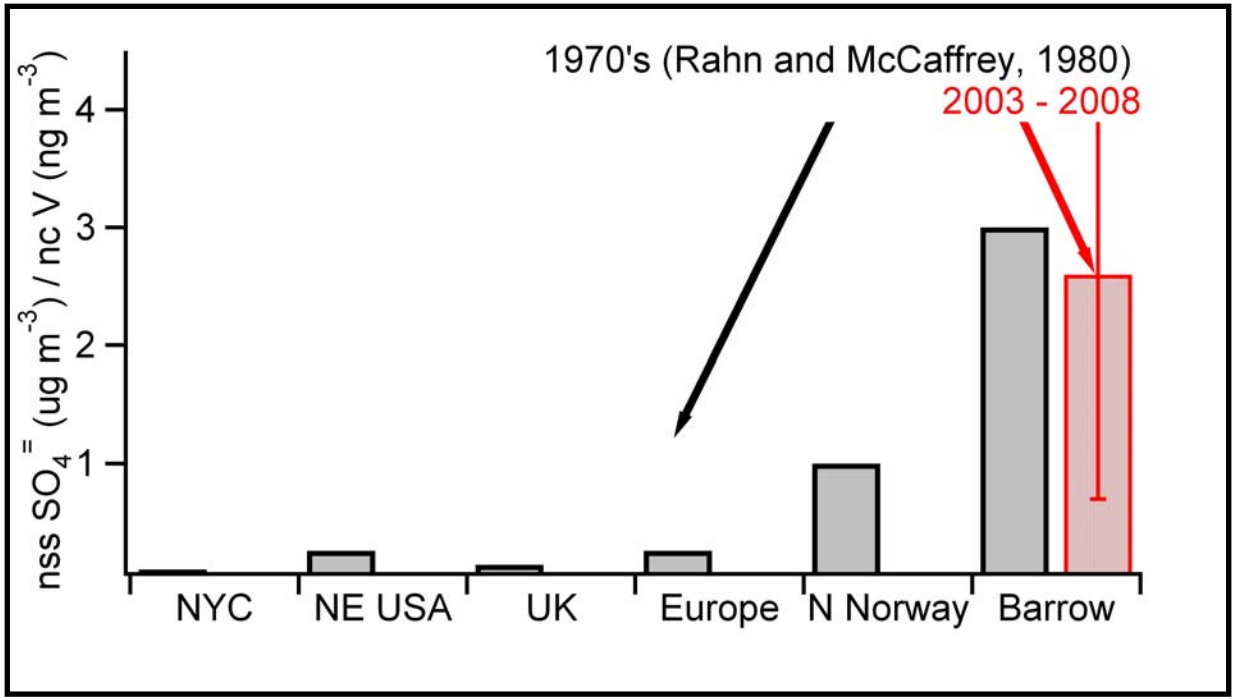


- Ratios within the Arctic were over an order of magnitude larger than those measured in mid-latitude source regions

- N. Norway was mid-way between mid-latitude and Arctic sites

- Higher Arctic ratios were attributed to oxidation of mid-latitude SO_2 while enroute to Barrow resulting in an aged version of mid-latitude aerosol

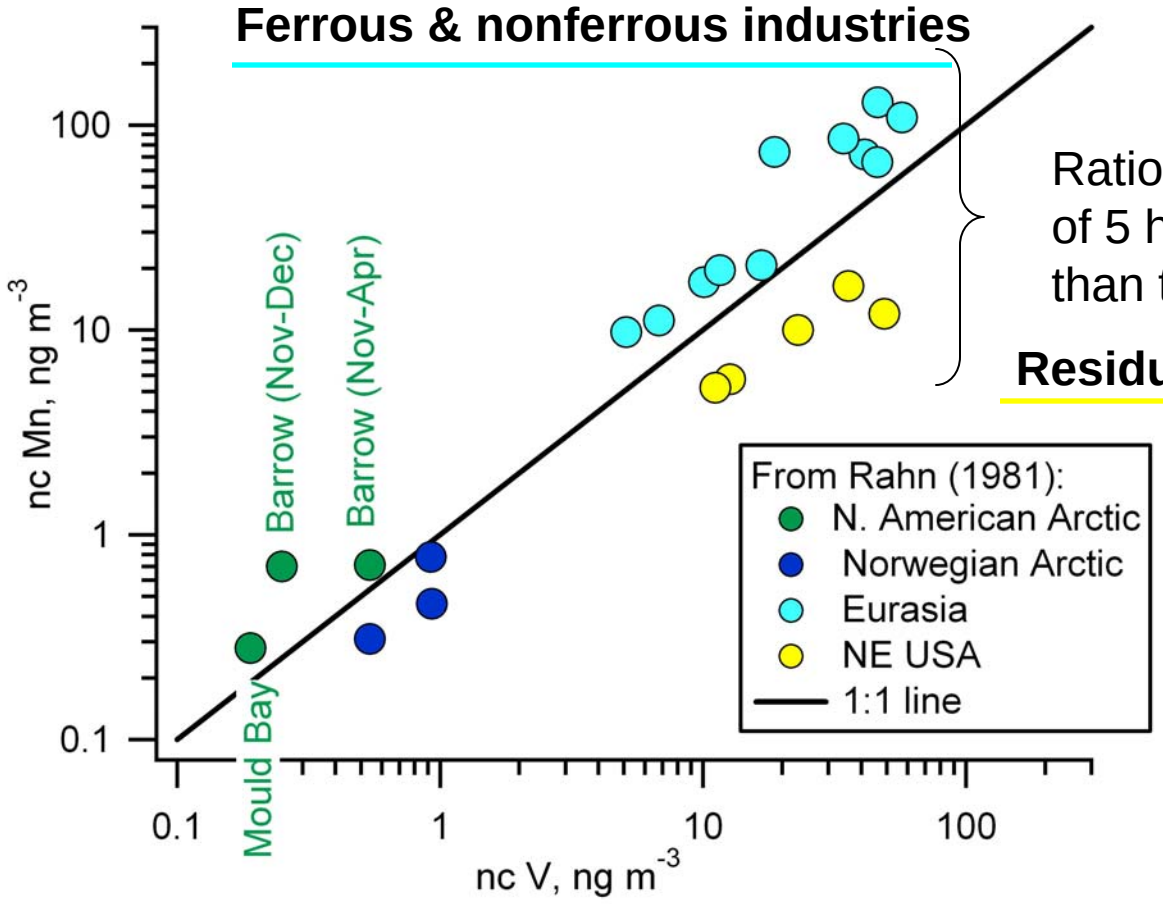
Haze season ratio of nss $SO_4^=$ to nc V as a tracer for mid-latitude pollution: Then and Now



- Concentrations of nss $SO_4^=$ and nc V have decreased but the ratio has not changed significantly
- Emissions are decreasing
- Measuring the same source as 30 years ago.

Winter time ratio of particulate nc Mn to nc V as a regional tracer

nc Mn / nc V
Ferro-alloy manufacturing / Residual oil combustion



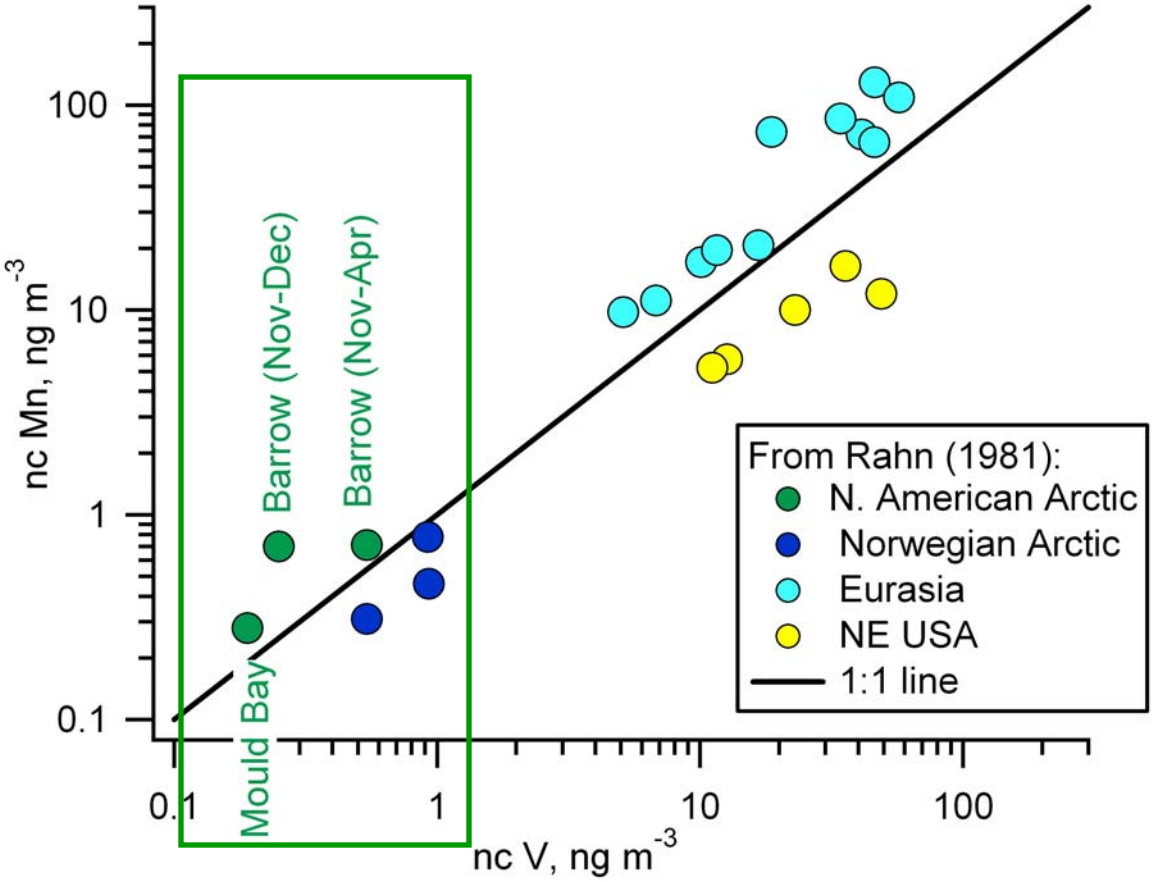
Ratios were a factor of 5 higher in Europe than the NE U.S.

Residual oil burning

Europe was a more significant source for Arctic aerosol than was the NE U.S.

Winter time ratio of particulate nc Mn to nc V as a regional tracer

nc Mn / nc V
Ferro-alloy manufacturing / Residual oil combustion

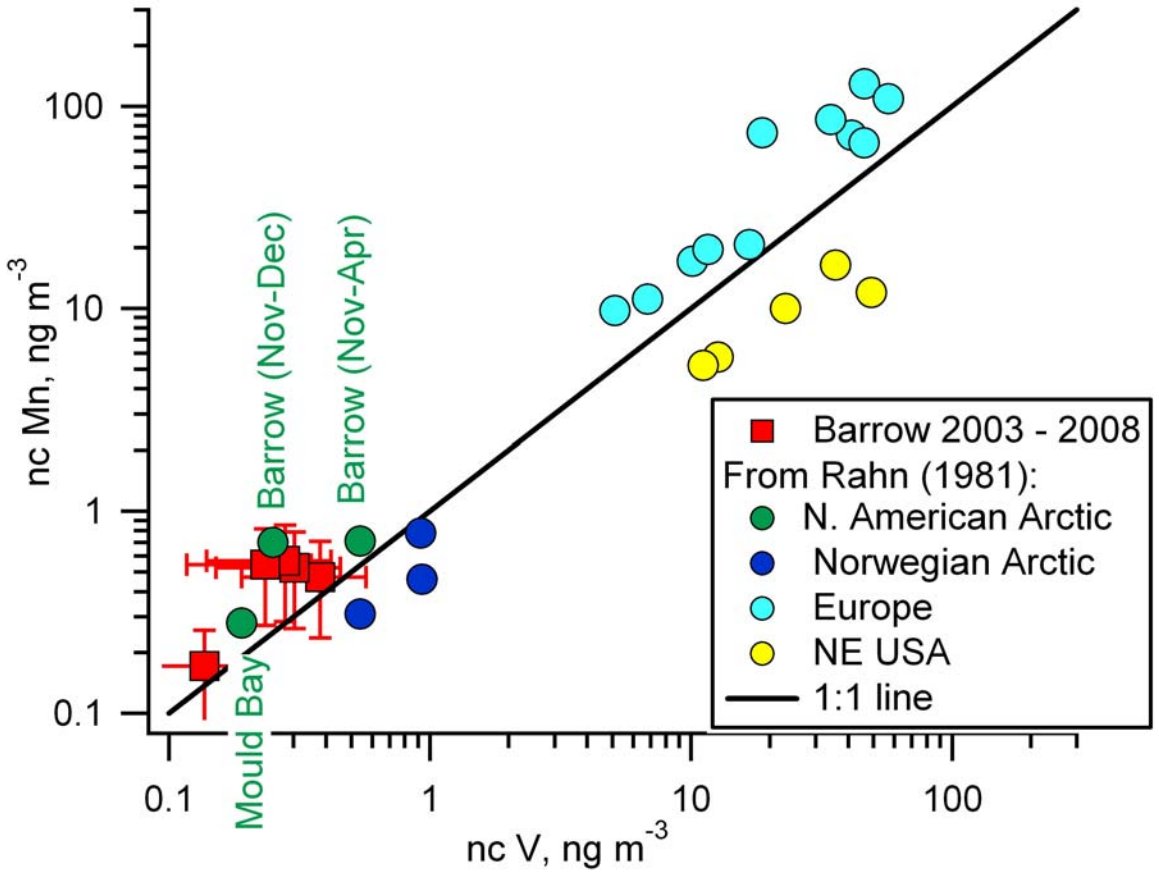


Compared to the Norwegian Arctic, N. American Arctic aerosol was more influenced by a source in addition to Europe.

- Soviet Union?

- Through the use of more elemental tracers and a study of the synoptic conditions at the time, this was later confirmed by Raatz and Shaw (1984) and Lowenthal and Rahn (1985).

Ratio of nc Mn to nc V as a regional tracer
Then and Now

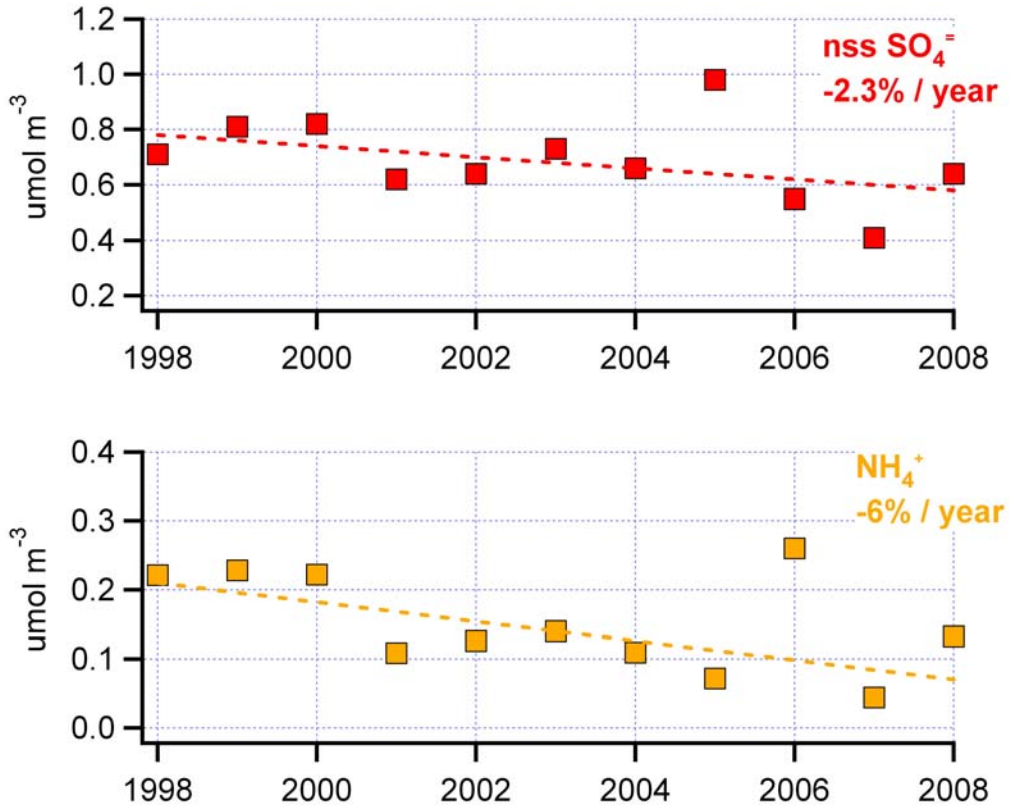


- 2003 – 2008 Barrow ratios are consistent with those from 1976 – 1978.

- The nc Mn / nc V ratio has remained the same at Barrow and distinct from the Norwegian Arctic.

- Emissions in the source regions to the Arctic have decreased over the past 3 decades but source regions themselves have not changed.

Changes in aerosol composition at Barrow during the **haze season**: 1997 - 2008

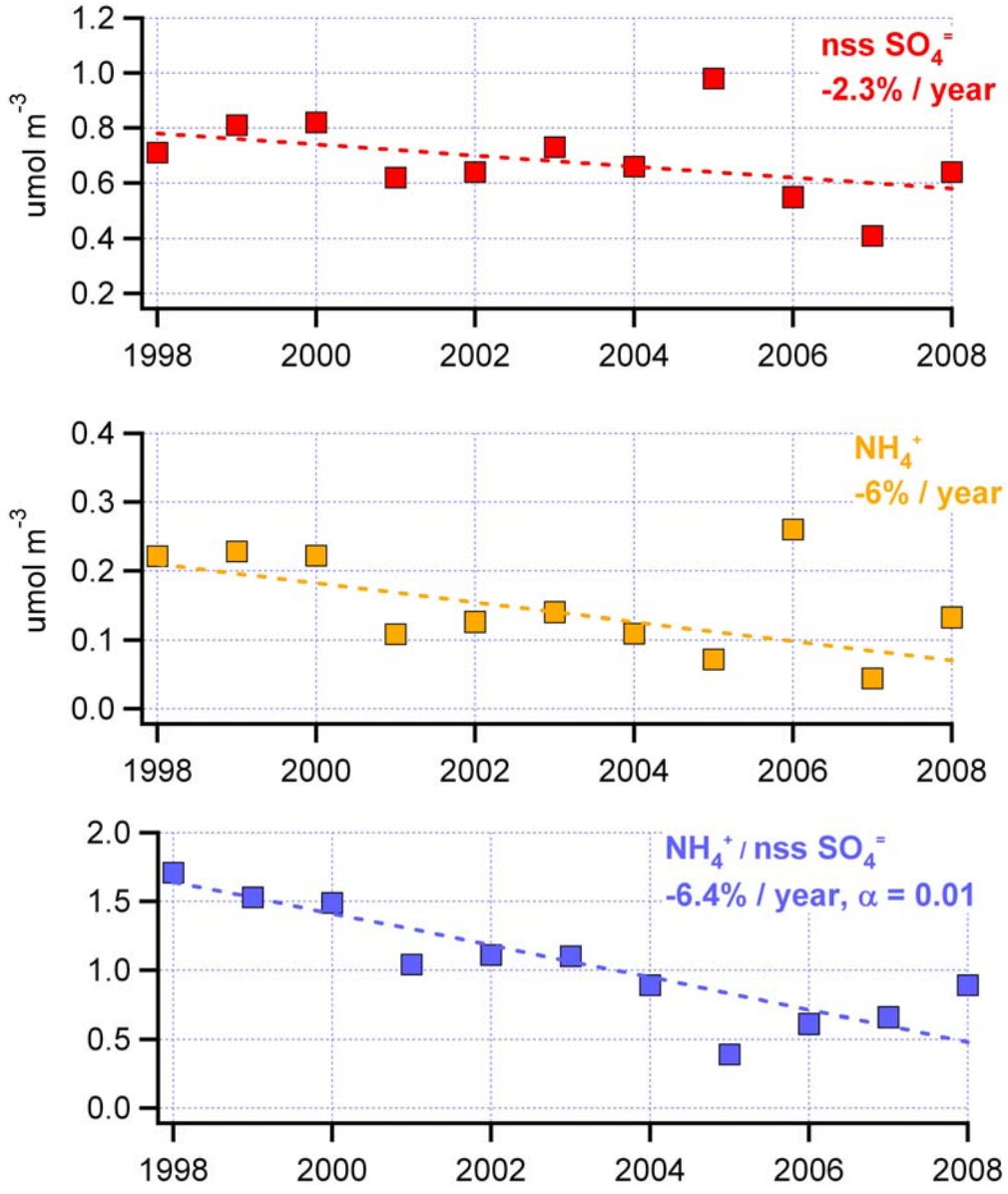


- Concentrations of nss $SO_4^=$ have decreased by about 2% per year over the past decade – consistent with 1976 – 2008 trend.

- Concentrations of NH_4^+ have decreased by 6% per year over the same time period.

- Why the difference?
  - Data show both components are decreasing in source regions to the Arctic
  - Emissions for Russia and EU as used in EMEP models show SO_x decreasing faster than NH_4^+ between 1997 and 2008.

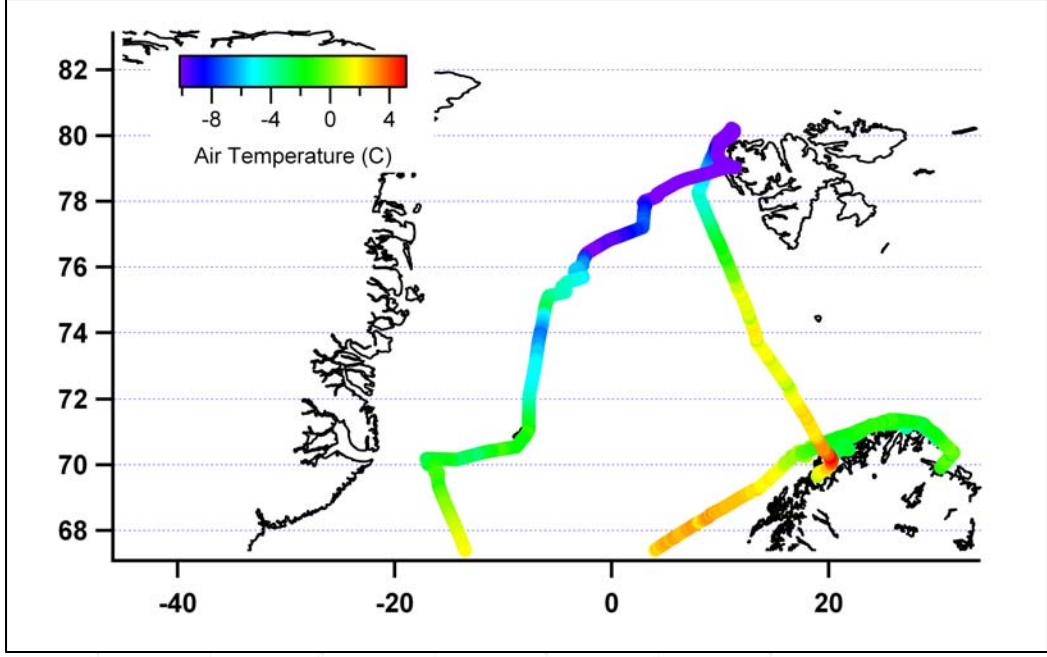
Changes in aerosol composition at Barrow during the **haze season**: 1997 - 2008

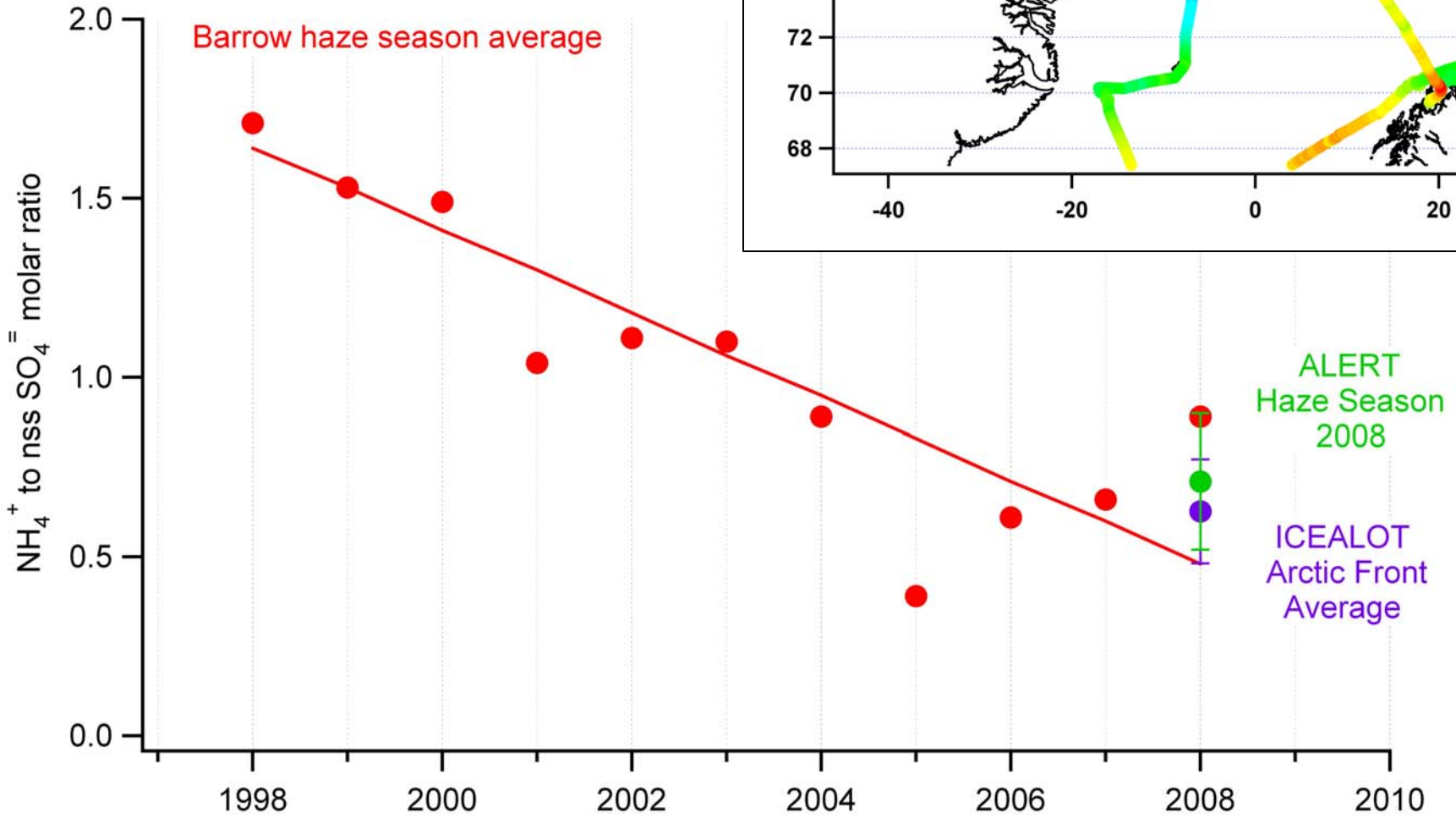


- NH_4^+ / nss $SO_4^=$ molar ratio has decreased by about 6% per year.

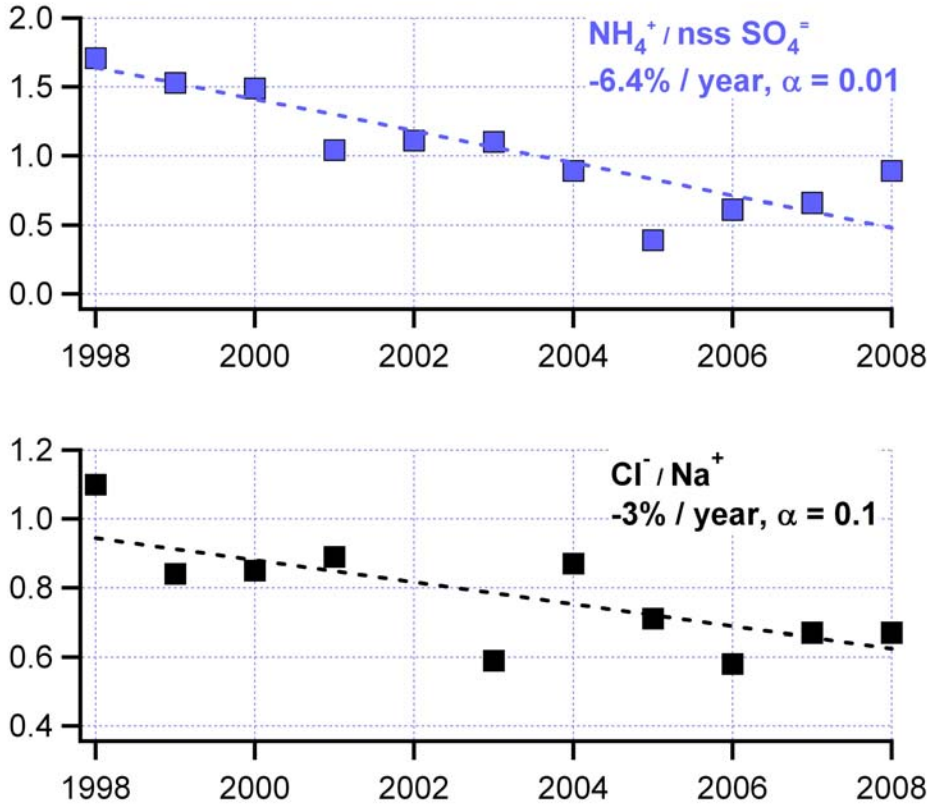
- The mid-latitude aerosol reaching the Arctic during the haze season is becoming more acidic.

Arctic wide phenomenon?





Changes in aerosol composition at Barrow during the **haze season**: 1997 - 2008



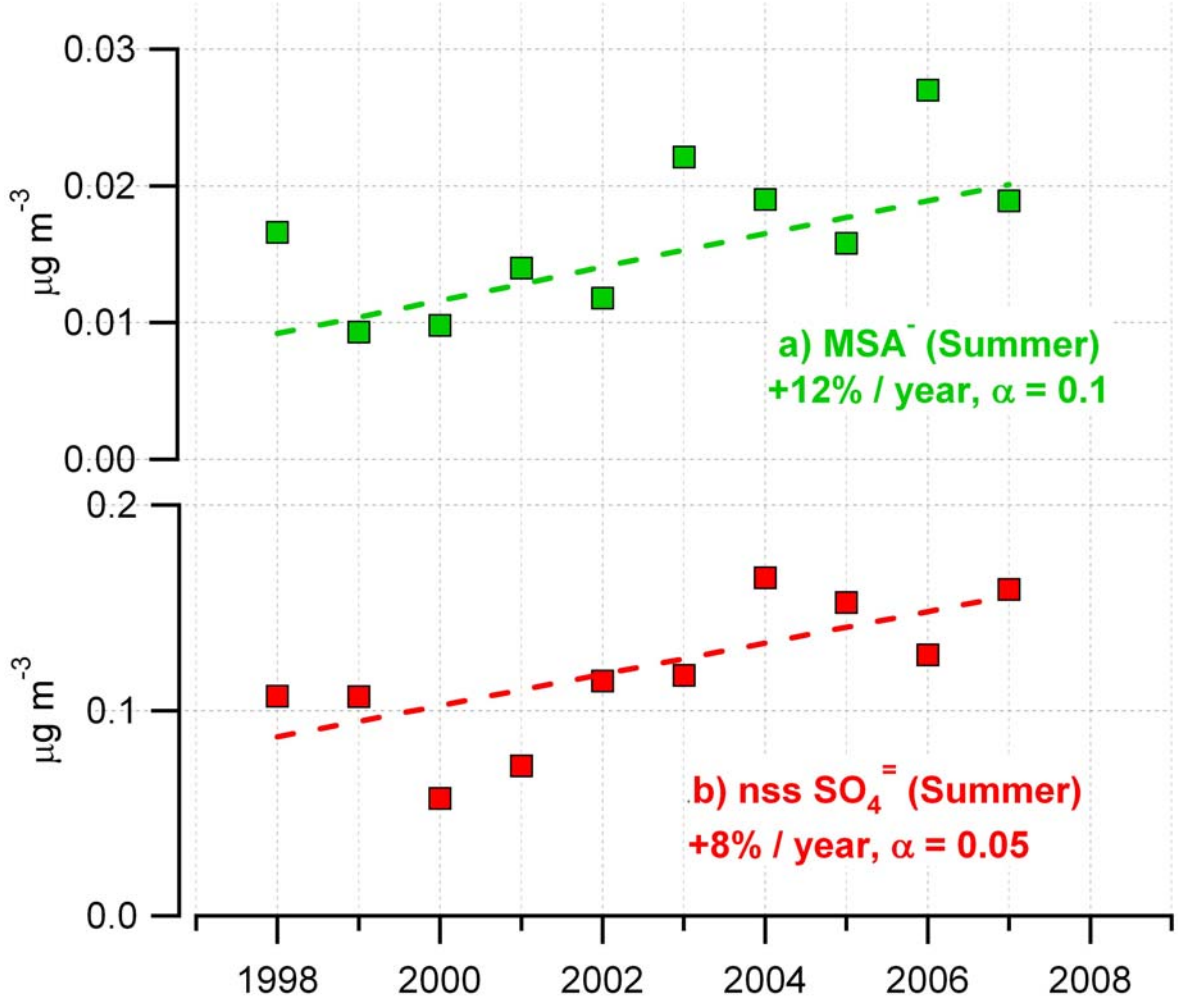
- Cl^- / Na^+ ratio is decreasing 3% per year. Why?

- The decreasing NH_4^+/nss $SO_4^=$ molar ratio results in an increasingly acidic anthropogenic aerosol that is available to react with sea salt in the Barrow boundary layer.

- The less neutralized $SO_4^=$ aerosol transported to Barrow may be resulting in more HCl displacement from the sea salt aerosol.

- Reduction in VOC lifetimes including CH4
- Impact reactions that produce and destroy O3
- Increase the production of highly reactive Cl - containing gases other than HCl such as ClNO2

Changes in aerosol composition at Barrow during the **summer**: 1997 - 2008



- Over the past decade, there has been a 12% per year increase in MSA during the summer months
- And an 8% per year increase in $SO_4^=$
- Why?

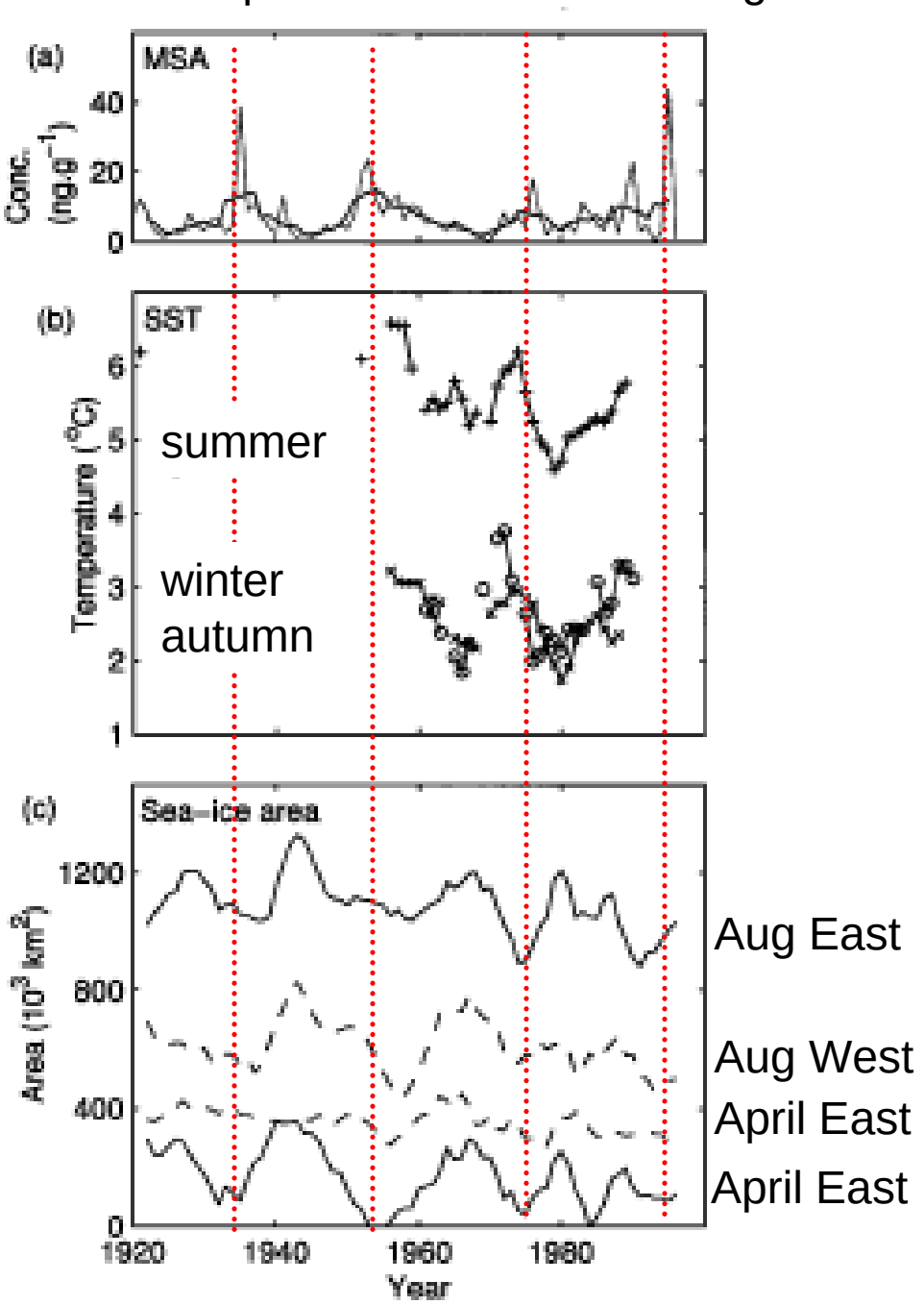
Methanesulfonic acid in a Svalbard ice core as an indicator of ocean climate

O'Dwyer et al., GRL, 2000

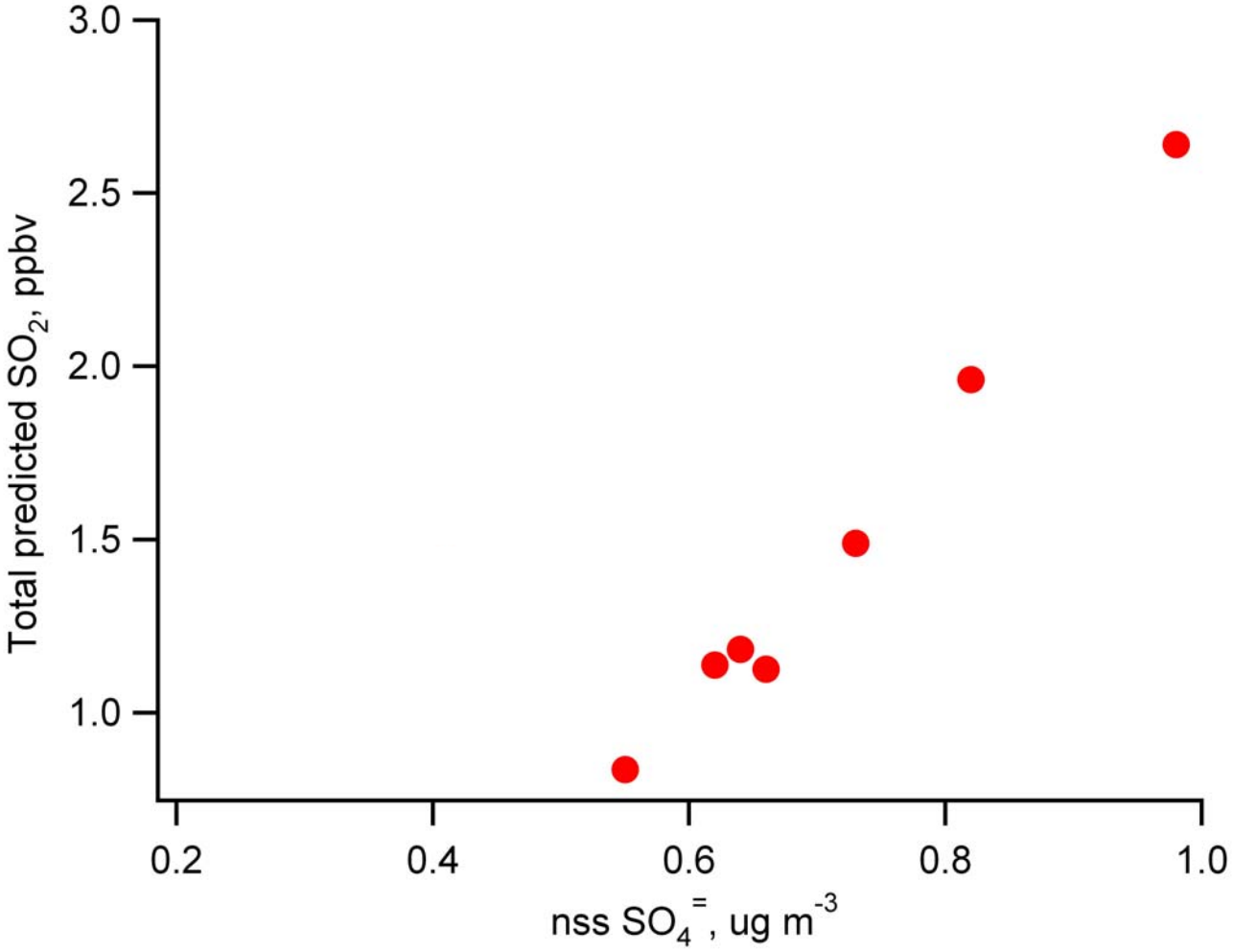
"MSA may be a useful proxy for past climate."

Ocean climate may be an indicator of current and future aerosol composition (biogenic, anyway).

MSA preserved in a Svalbard glacier



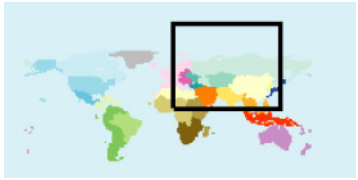
Flexpart-predicted SO_2 and Measured $SO_4^=$ at Barrow

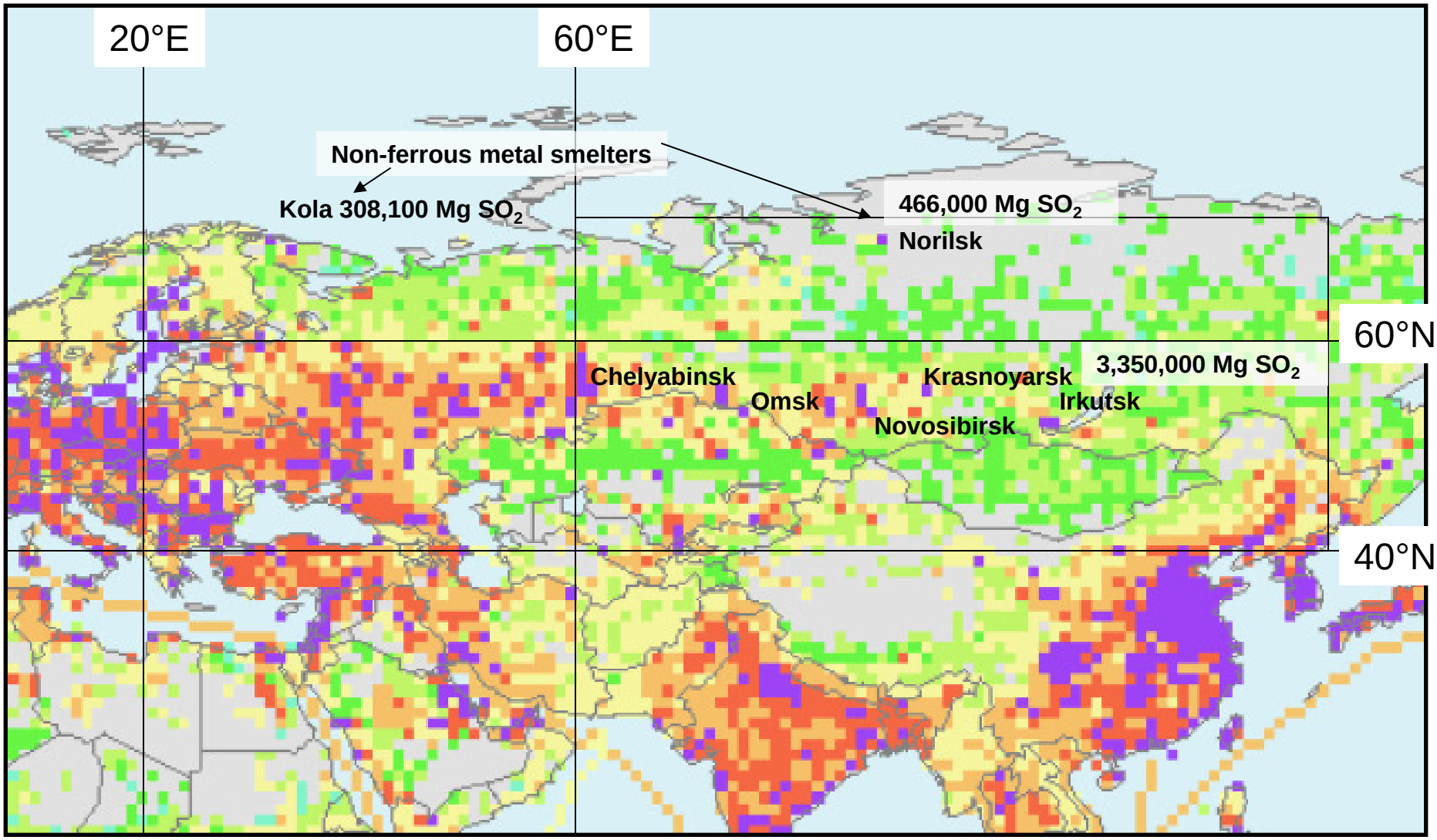


- SO_2 is overpredicted relative to $SO_4^=$ by about an order of magnitude
- Still, this level of agreement in trends of predicted SO_2 and measured $SO_4^=$ says Flexpart is getting transport to Barrow right.

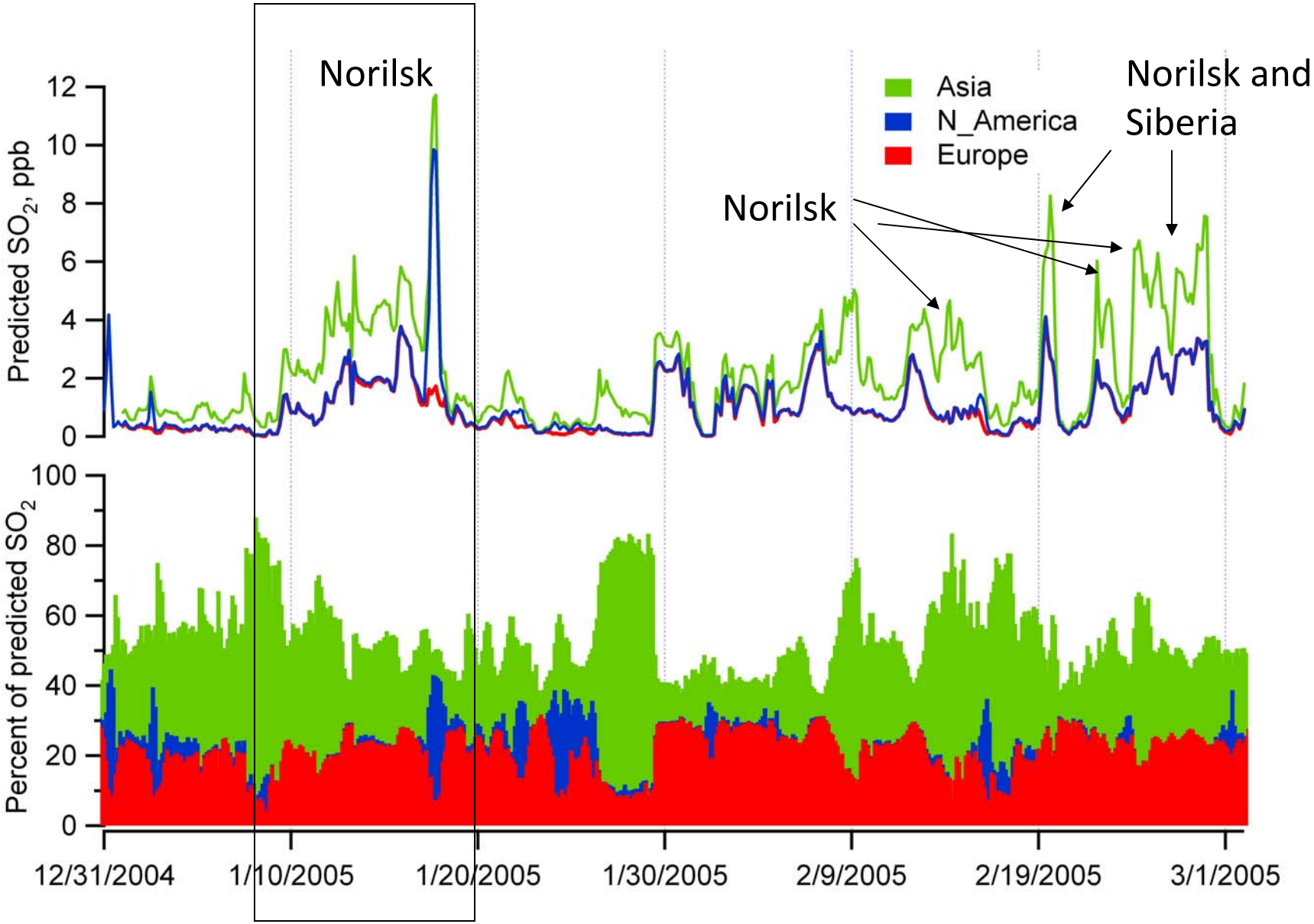
Netherlands Environmental Assessment Agency

EDGAR Map: Sulphur oxide (SO2)





Predicted SO_2 for January and February 2005



What fraction of $SO_4^=$ is due to transport from Norilsk vs. other sources?

National Oceanic and Atmospheric Administration

• NOAA PMEL Atmospheric Chemistry Group data can be found at:

http://saga.pmel.noaa.gov/data/

• Empirical parameterizations for relating f(RH) to composition are available in

Quinn et al., GRL, 2005; Quinn et al., JGR, 2006

• We have a great interest in combining data with models to explain seasonality of Barrow data as well as sources and decadal scale trends.