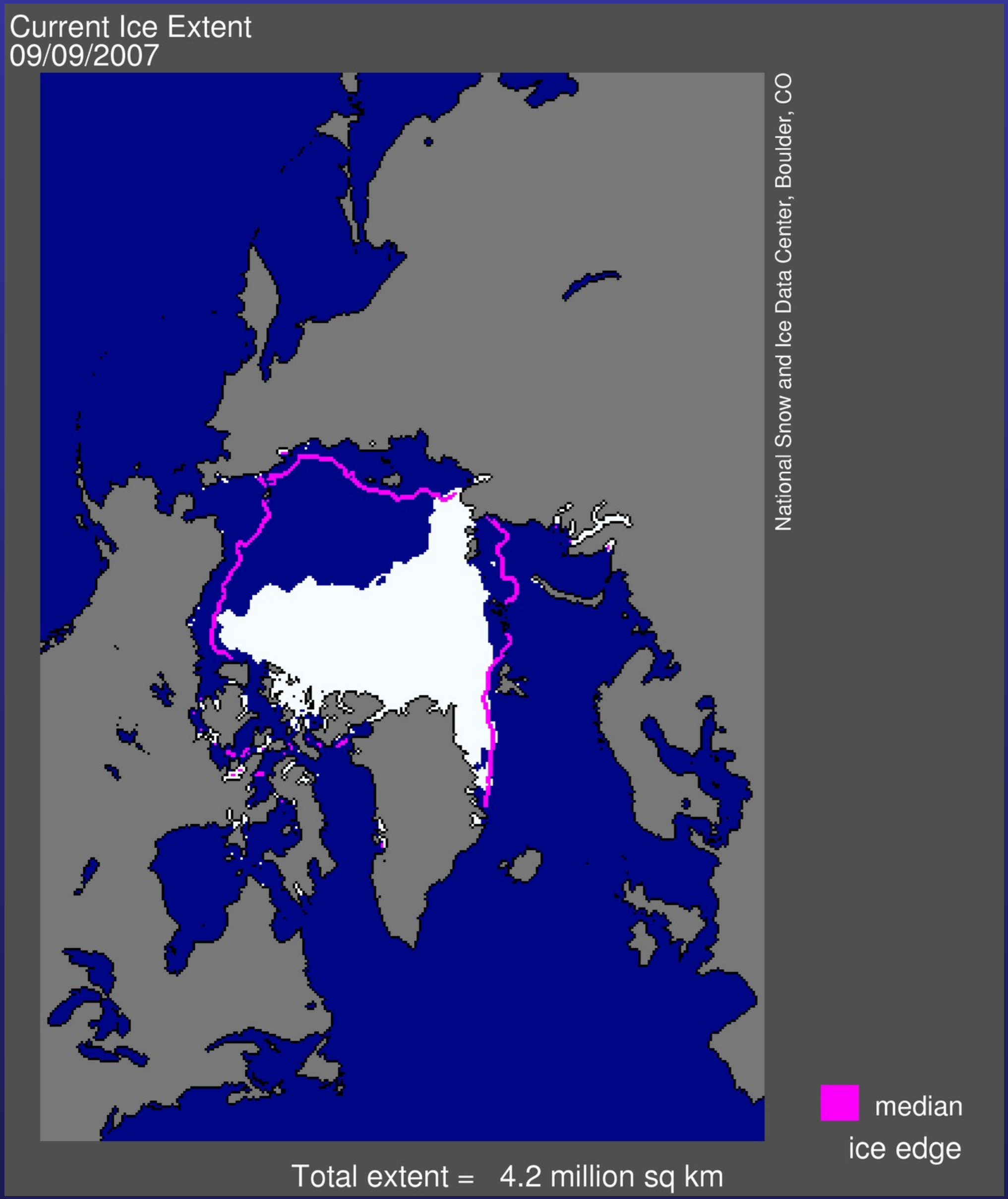
Motivation for NOAA Mission



Arctic sea ice at record lows (esp. this summer)

Remaining ice is thinner (less thick, multiyear ice)

GCMs aren’t producing such rapid and extensive loss

Strong ice-albedo feedback to global climate

Ice free summertime Arctic in 5-20 years?!

What human-caused processes *other* than climate change from long-lived GHG may increase Arctic warming and/or sea ice melt?

- Lower tropospheric warming due to absorption of solar radiation by soot particles
- Decrease in snow albedo by deposited soot
- Increase in IR emissivity of clouds by aerosol indirect effect
- Tropospheric O_3 forcing (local IR, probably small effect)

These are all short-lived species and therefore respond RAPIDLY to changes in emissions

(role of meteorology and multi-year cycles?)

2) Lower tropospheric warming due to absorption of solar radiation by soot particles

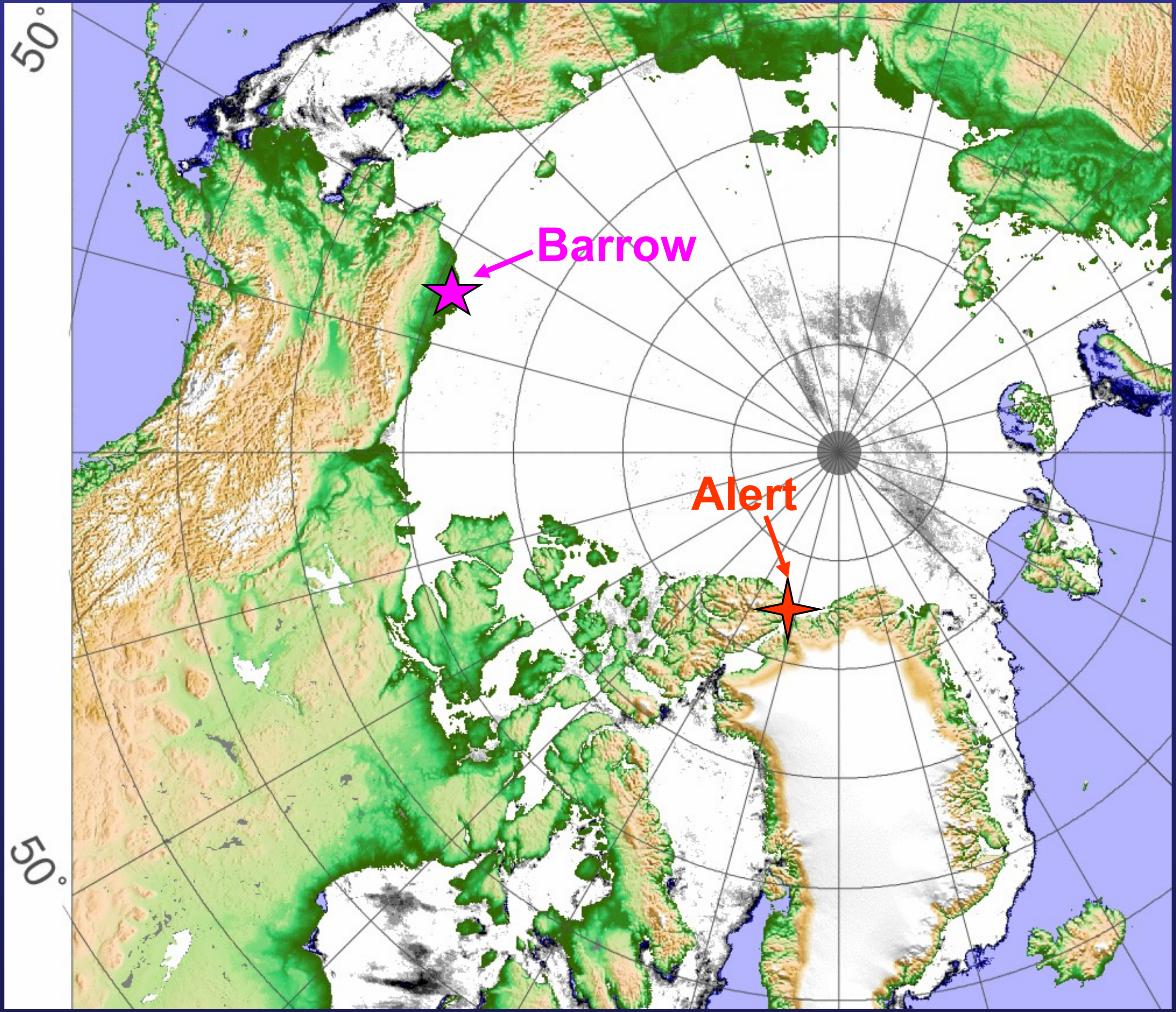
3) Decrease in snow albedo by deposited soot

4) Increase in IR emissivity of clouds by aerosol indirect effect

These 3 processes are all driven by aerosol and cloud properties and interactions and are important in winter and spring.

Arctic springtime aerosol properties are dominated by anthropogenic emissions and transport (Arctic haze).

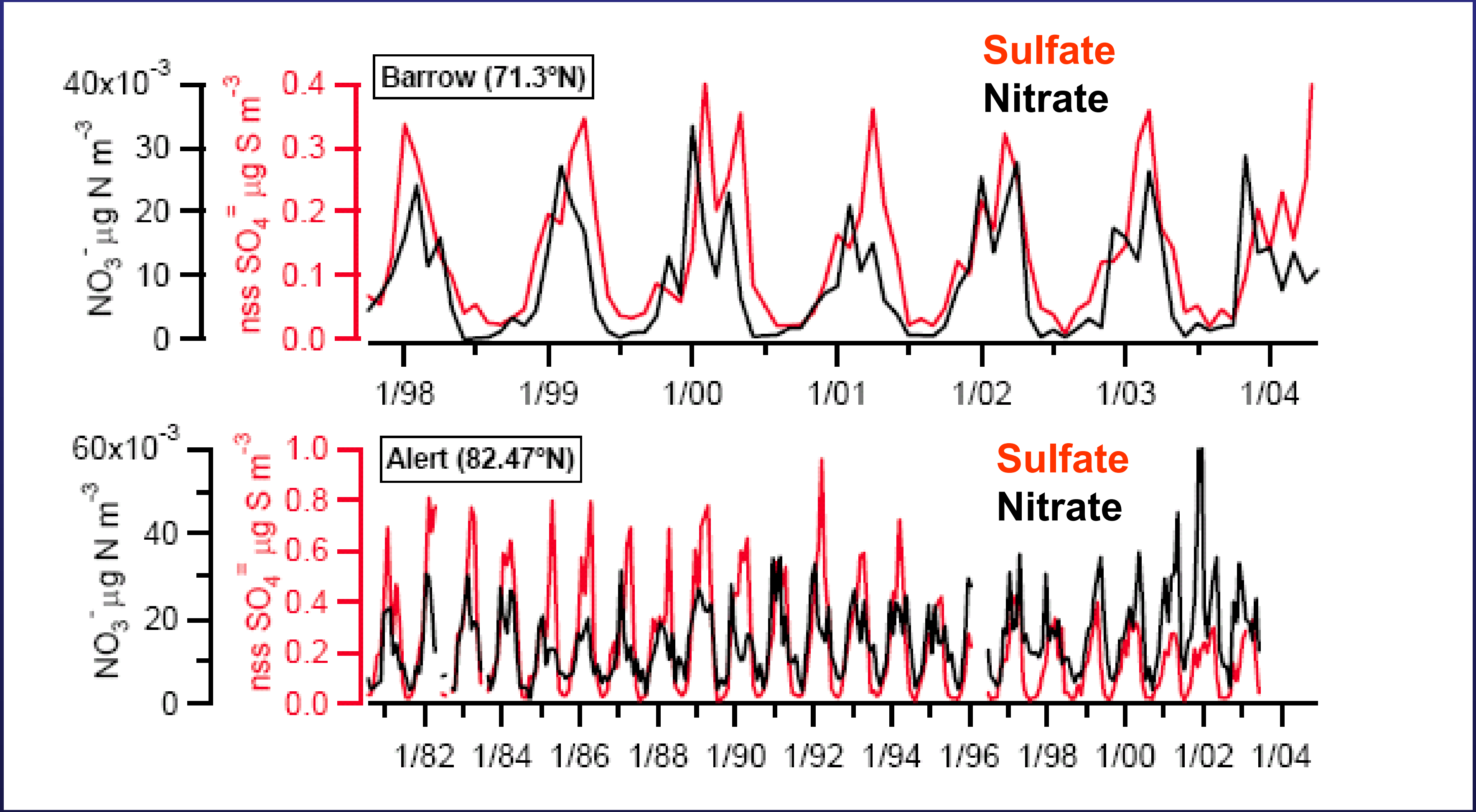
Two long-term North American surface sites: Barrow, Alaska and Alert, Canada



Monthly mean aerosol mass shows consistent annual cycle

- Peak in January-April--variation with altitude?
- Mostly sulfate, nitrate ~10% of sulfate
- Little info on organic mass
- Arctic-wide

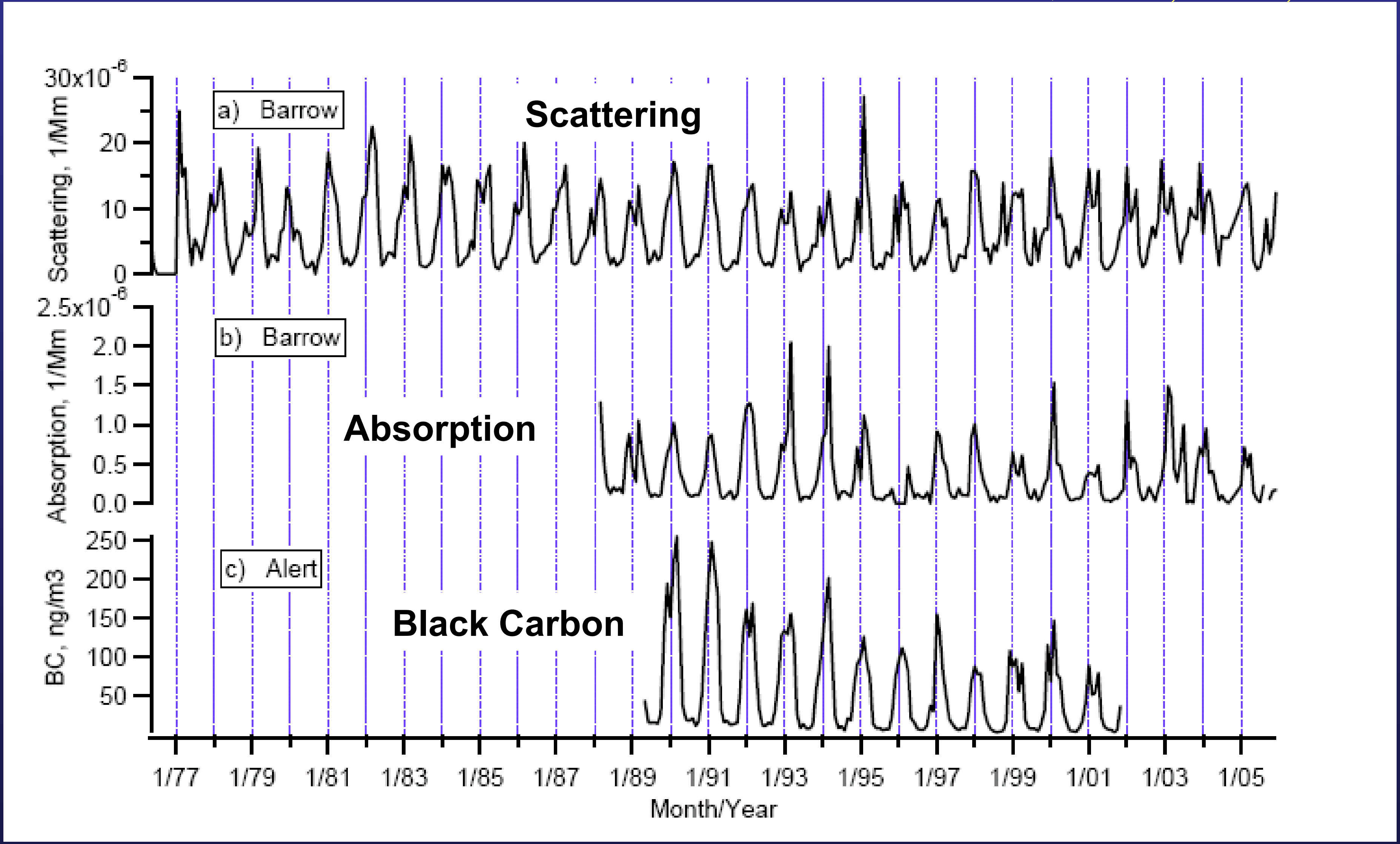
Quinn et al., *Tellus B, 2007*

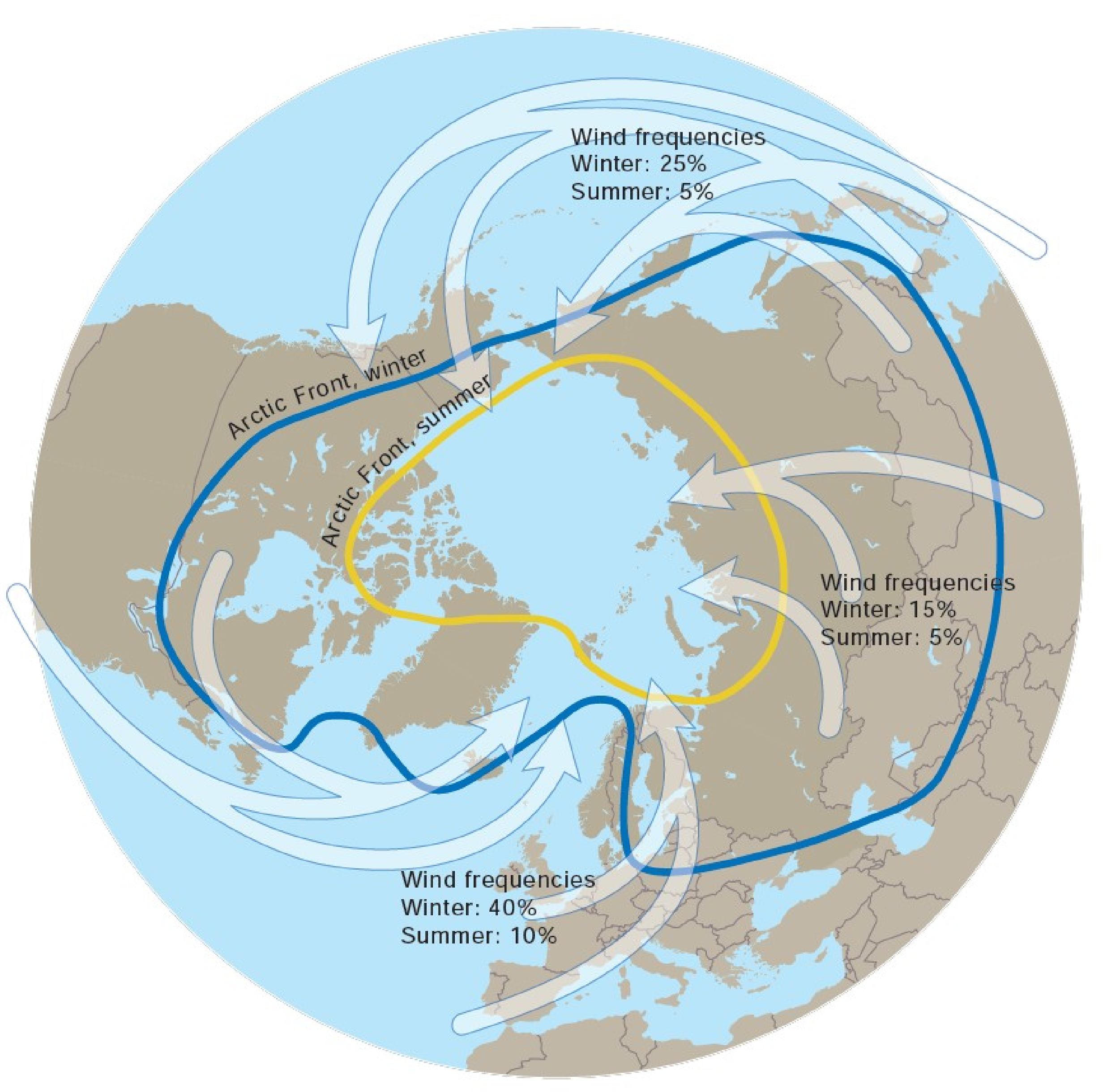


Similar annual cycle for scattering, absorption, black carbon (soot)

- Decrease in absorption and black carbon since the Soviet industrial decline?

Quinn et al, Tellus B, 2007

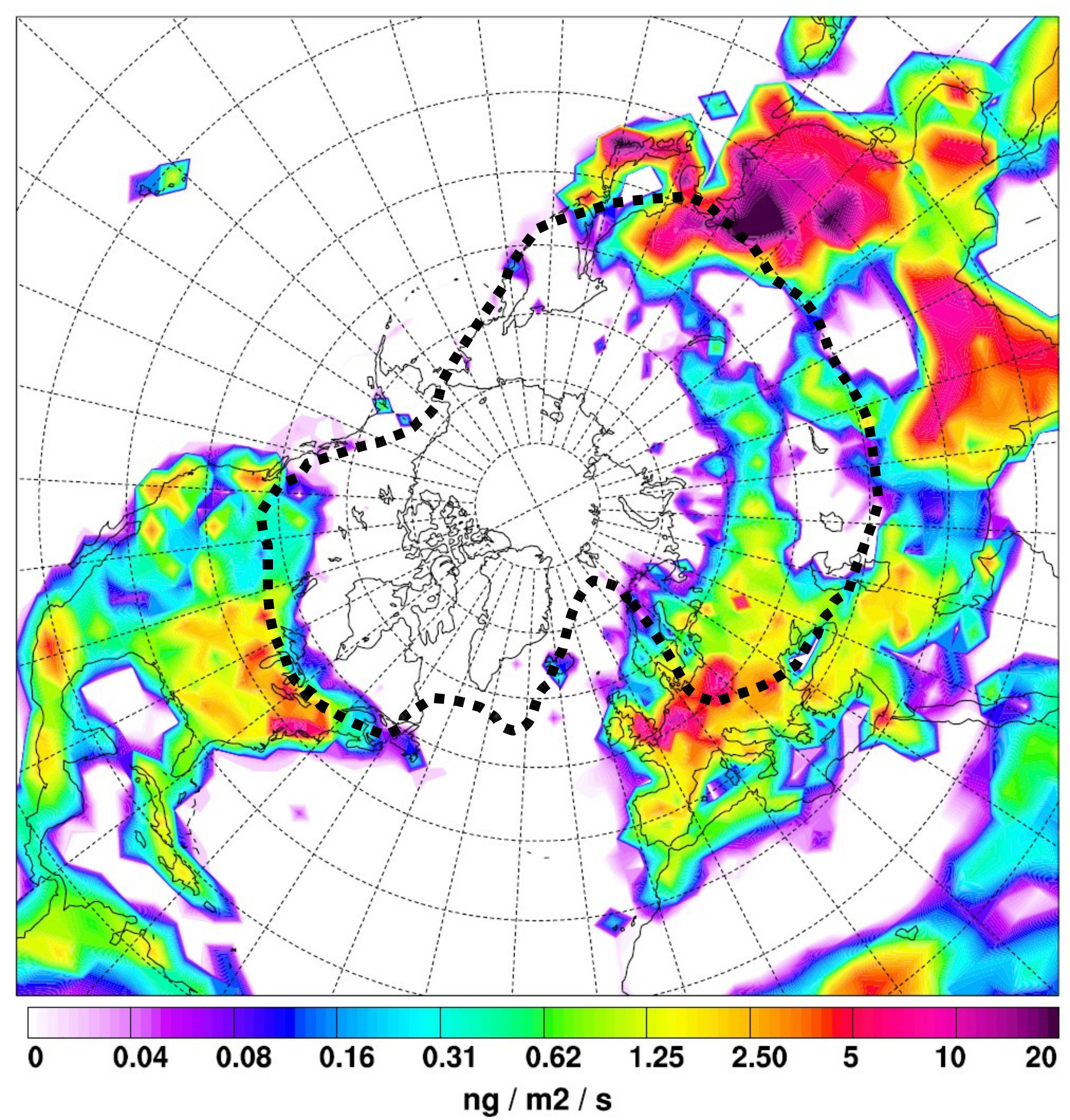




Sources for surface haze generally lie within the Arctic front

Layers aloft may have sources further south (if they can survive cross-front processes)

Arctic Monitoring and Assessment Programme, 2006

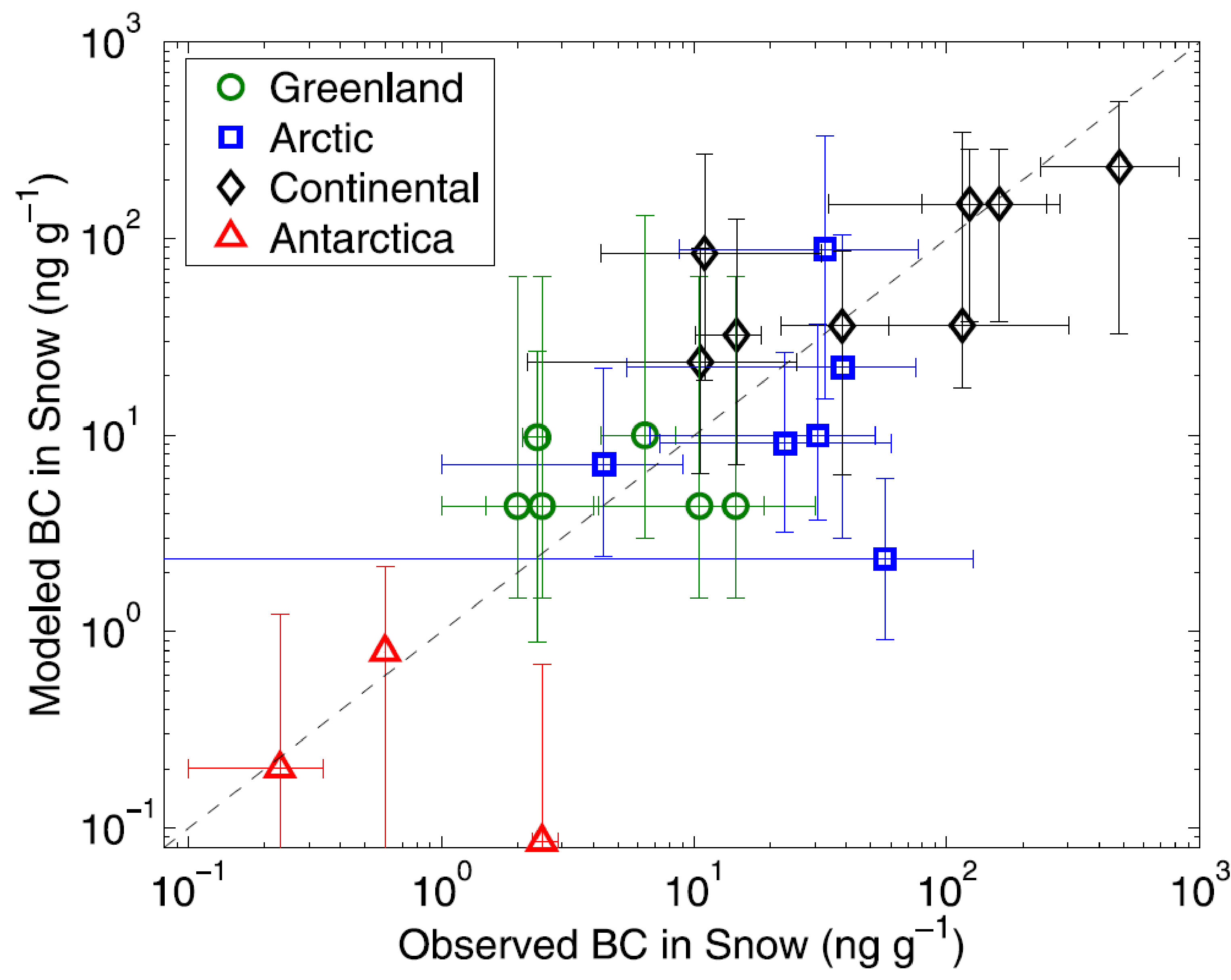


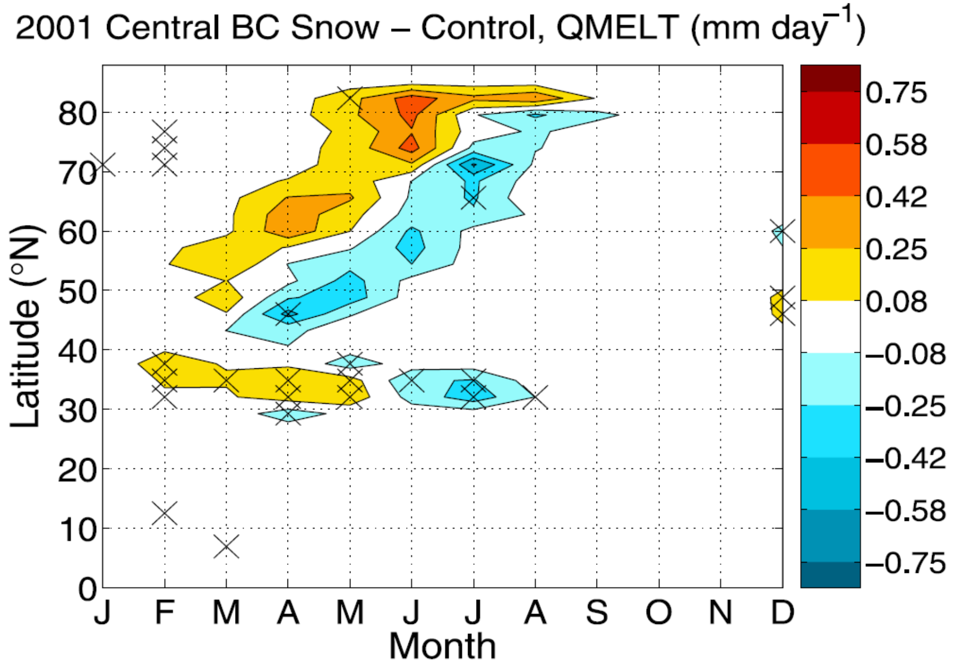
Anthropogenic sources of soot (industrial and biofuel)

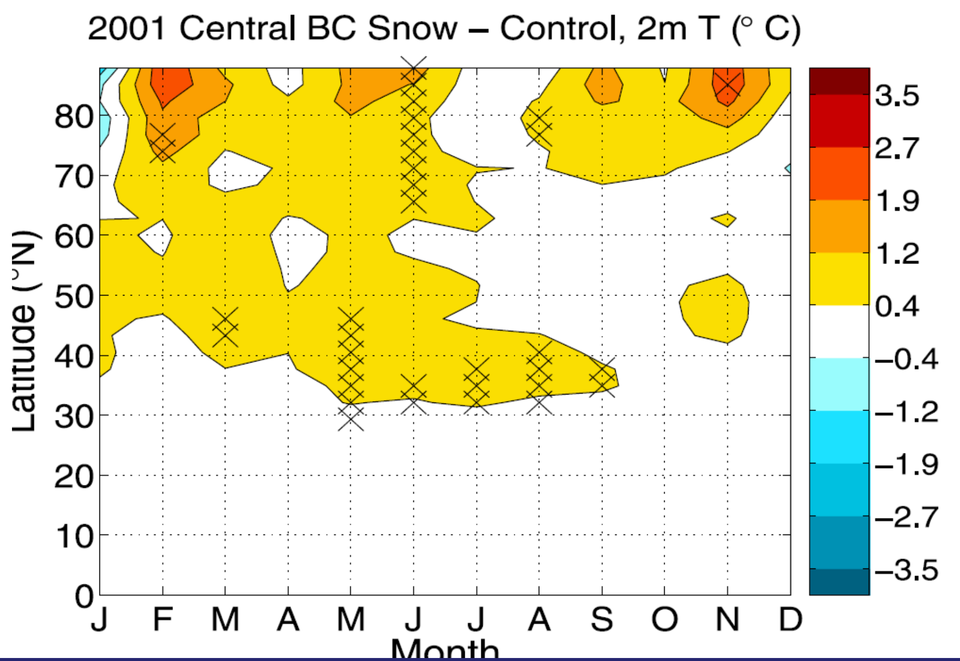
Sources in northern Europe and NE China are consistently within or near the mean position of the Arctic front.

Stohl et al., 2006

Flanner et al., 2007 Soot/snow/climate model

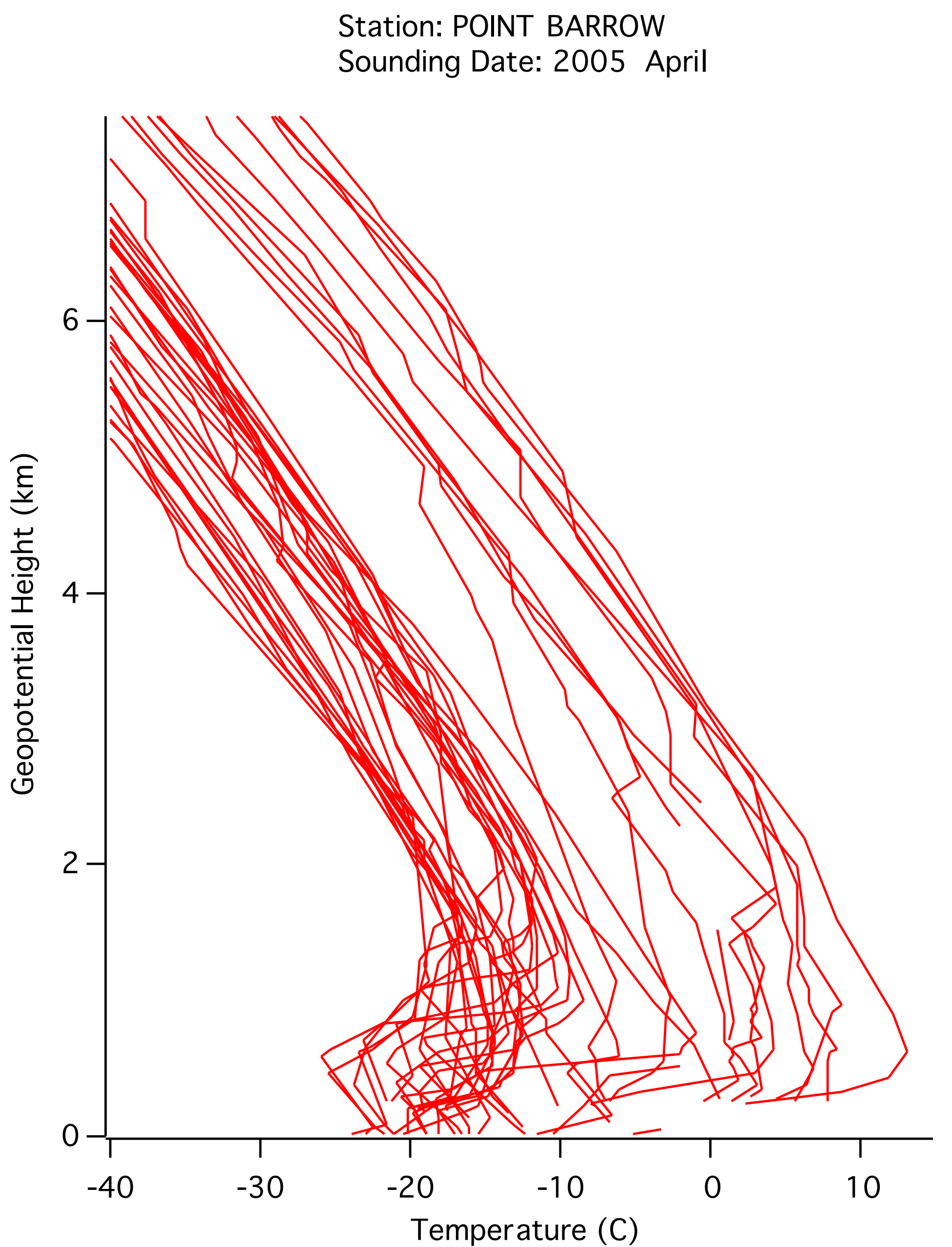






"BC in snowpack can provoke disproportionately large springtime climate response because the forcing tends to coincide with the onset of snowmelt, thus triggering more rapid snow ablation and snow-albedo feedback."

How is soot deposited? (The Arctic is stable!)



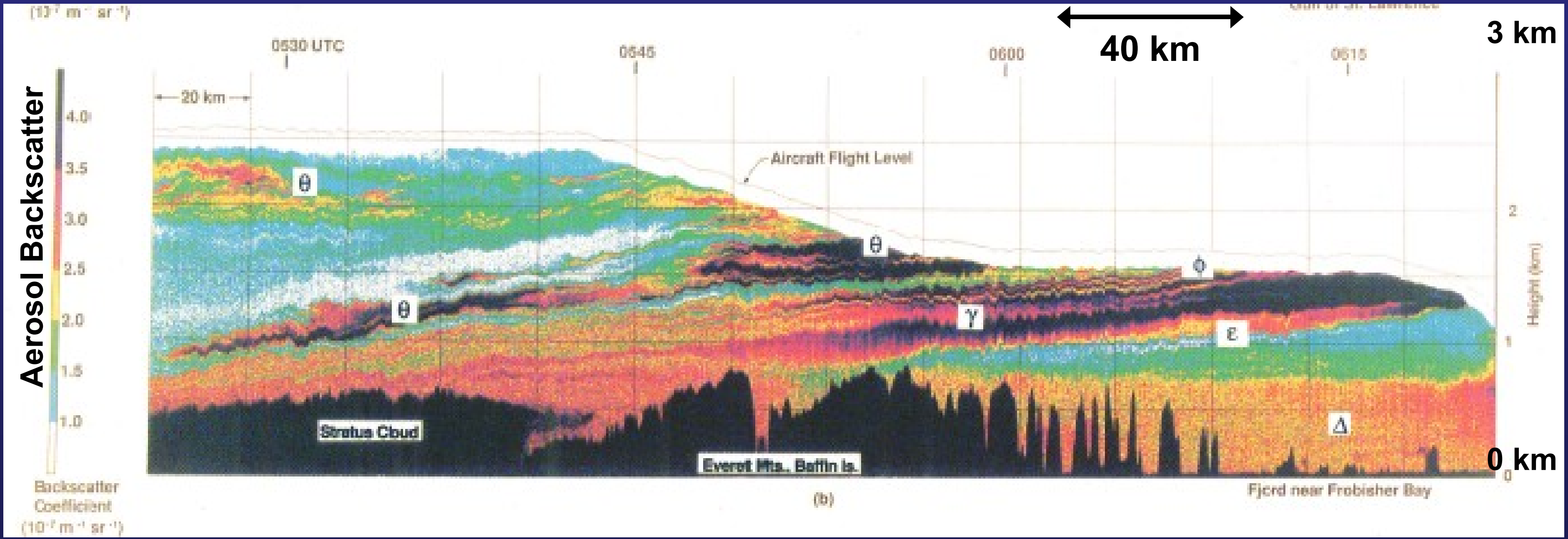
Strong inversion:

- Surface often decoupled from air aloft
- Clouds can (and do) have liquid water even in winter and spring
- Clouds may be warmer than the surface
- This inversion occurs over ice surface, not over open ocean

Above the ice surface, result is very stable atmosphere, stratiform layers, and decoupling of surface aerosol from transport aloft.

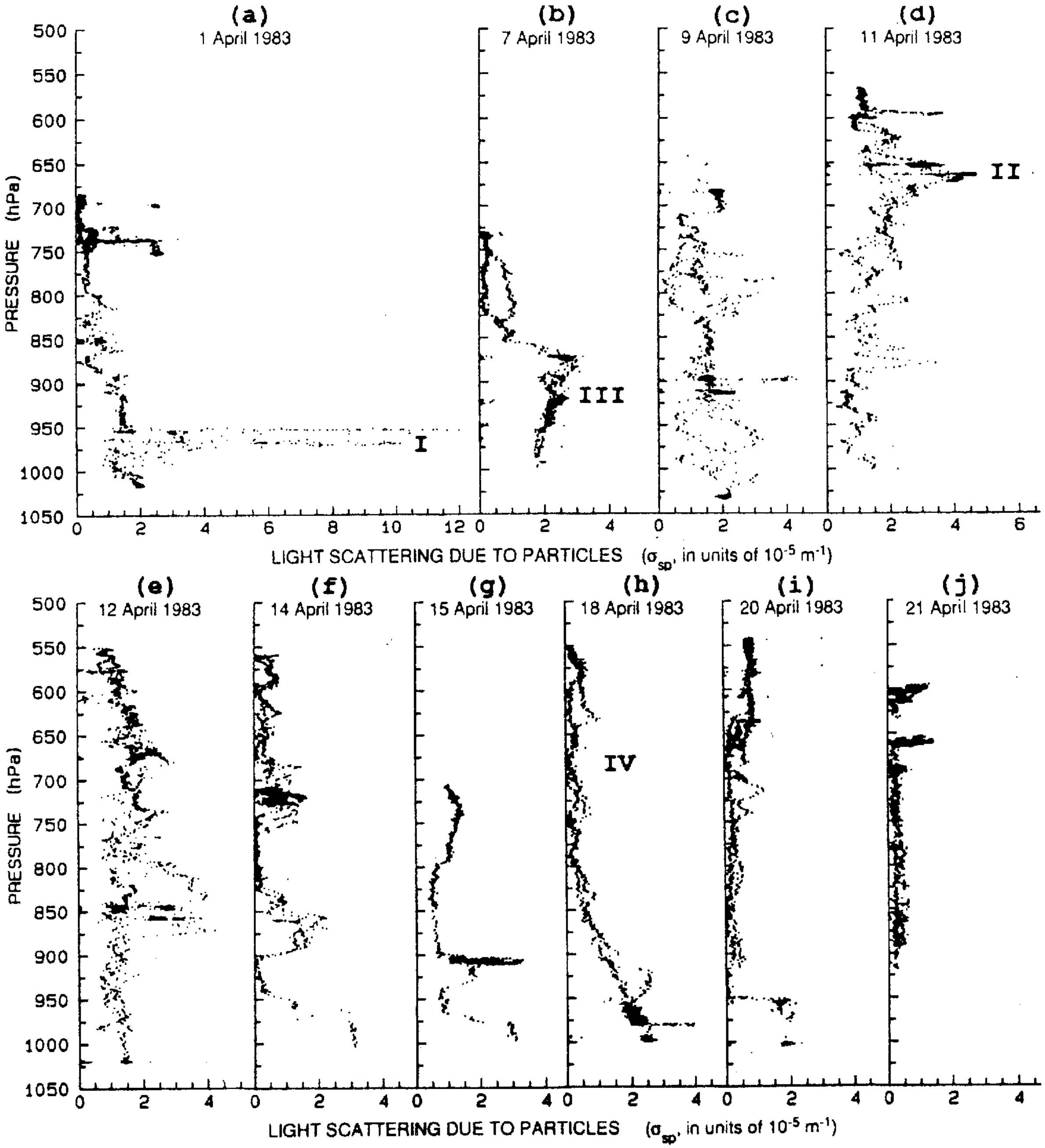
→ A reason for an *aircraft* mission in the deep Arctic.

Surface and layers aloft may be linked only via radiation and mass transfer through clouds & precip.

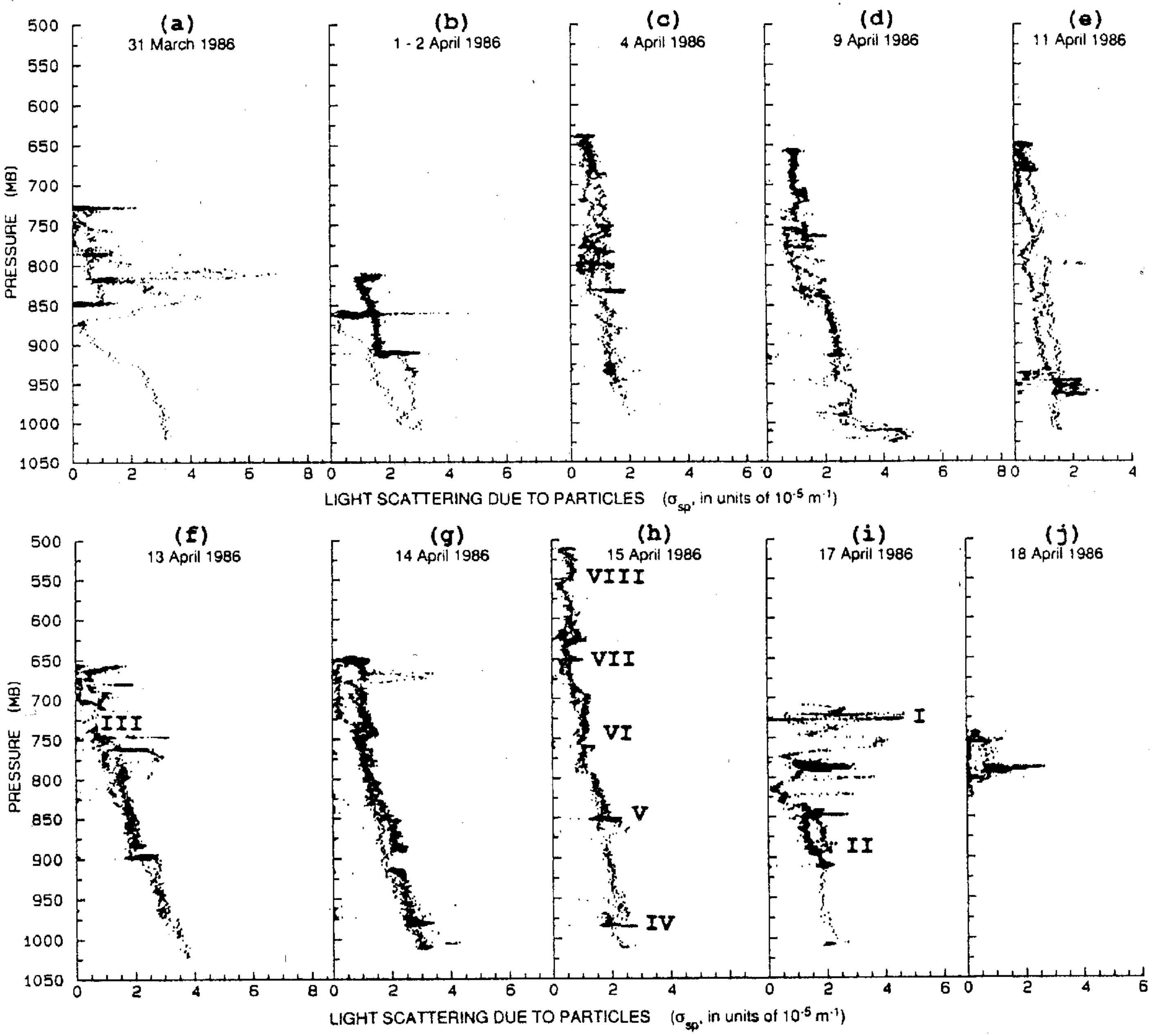


Downward-looking airborne aerosol lidar image of haze layers near Baffin Island, Canada in 1986. (Radke et al., 1989)

April 1983: Dense pollution layers aloft



April 1986: Layers aloft, more diffuse near surface



Direct radiative forcing of the haze layers is poorly quantified (literature varies), but generally:

•Lower atmospheric heating rates of *0.1-0.5 K/day* are calculated in springtime

•Single scatter albedo [scattering/(scattering+ absorption)] is critical in determining atmospheric heating *vs.* surface cooling

•IR emissions from the layers appear to be important

•Hygroscopicity, which changes single scatter albedo and IR emissions, is virtually unmeasured in Arctic

•Sun angle and surface albedo play important roles

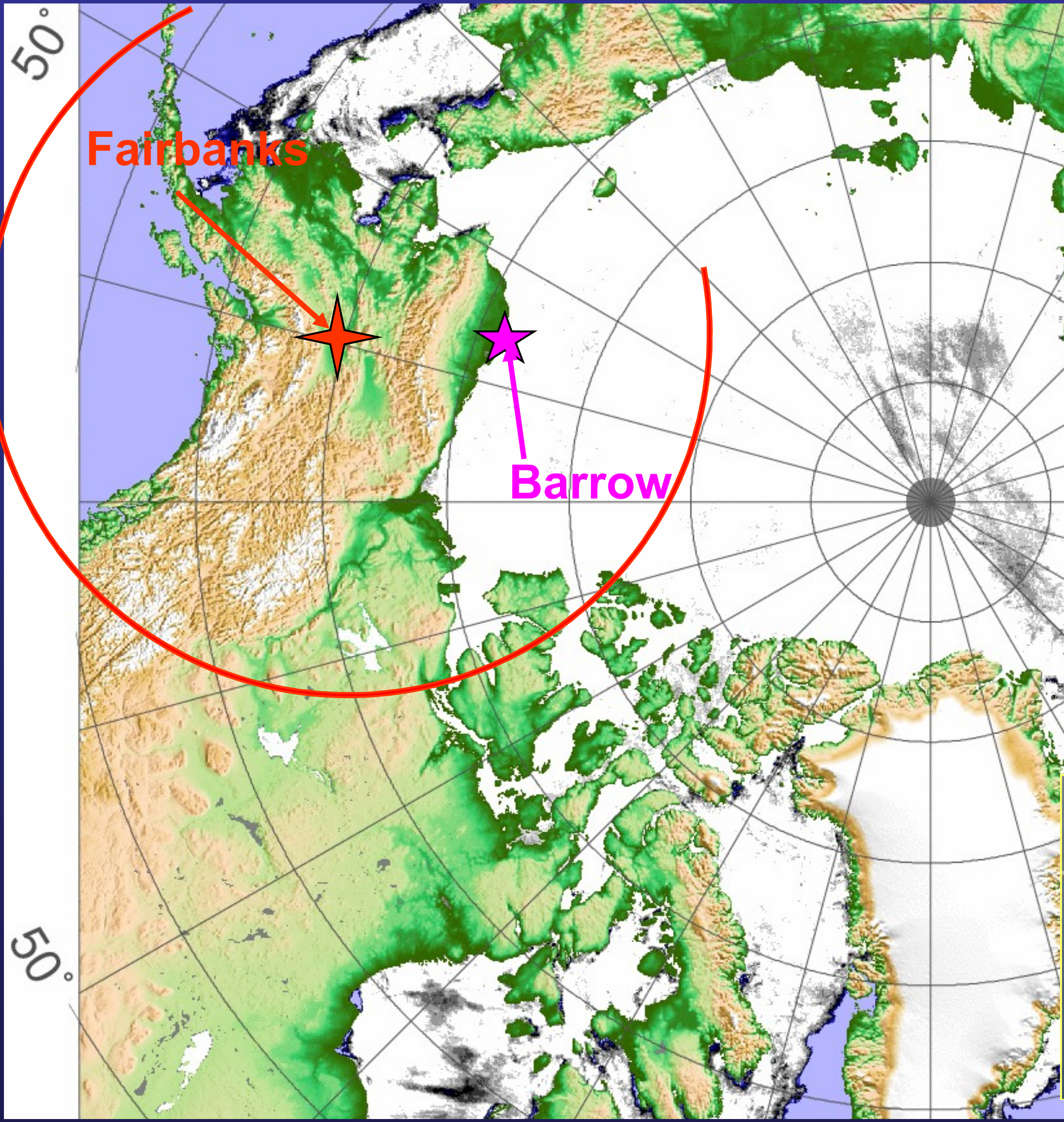
Summary of processes we will study

- *Direct effect:* Particle sources, chemical and optical characteristics, soot abundance, source type, transport, removal

- *Indirect effect:* Cloud properties, particle effects on clouds, cloud dynamics

- *Snow albedo effect:* Aerosol removal by nucleation and precipitation scavenging

NOAA WP-3D out-and-back Range from Fairbanks



- 3 big airports
- Accomodations
- Infrastructure
- Shipping
- Not remote, but close to Arctic

Aerosol Physical and Optical Properties Measurements

Abbrev.	Name	Specs	Investigators
LTI	low turbulence inlet		C. Brock (NOAA)
NMASS	nucleation mode aerosol size spectrometer	0.004-0.055 μm (5 CPCs)	C. Brock (NOAA)
UHSAS	ultrahigh sensitivity aerosol size spectrometer	0.07-1 μm	C. Brock, J. Cozic (NOAA)
WLOPC	white-light optical particle counter	0.5-9 μm	C. Brock, A. Wollny (NOAA)
CRD-AES	cavity ringdown-aerosol extinction spectrometer	3-λ, 3 RH (7, 60, 90%), <2% unc.	D. Lack (NOAA)
PSAP	particle soot absorption photometer	3-λ, 7% RH	D. Lack (NOAA)
CCN	cloud condensation nucleus counter	3 s-saturations serially	T. Nenes, R. Moore (Ga. Tech)

Aerosol Composition, Cloud, and Radiation Measurements

Abbrev.	**Name**	**Specs**	**Investigators**
PILS	particle-into-liquid sampler, vials	<0.8 µm, IC for major ions	J. de Gouw, T. Quinn (NOAA)
AMS	C-TOF aerosol mass spectrometer	<0.6 µm	A. Middlebrook, R. Bahreini (NOAA)
SP2	single-particle soot photometer	0.15-1 µm	R.-S. Gao, S. Schwarz (NOAA)
PALMS	particle analysis by laser mass spectrometry	0.3-3 µm, counterflow virtual impactor	D. Murphy, K. Froyd (NOAA)
Cloud probes	CIP, PIP CDP, CAS, King and J-W LWC	0.5-6200 µm	AOC, C. Brock, S. Lance (NOAA)
SSFR/CG4	solar spectral flux radiometer and pyrgeometer	.350-1.670 µm, up- and down-welling	P. Pilewskie (U. of Colo.), W. Gore, T. Trias (NASA)
ZAPHROD	spectral actinic flux radiometer	up- and down-welling	H. Stark (NOAA)

Abbrev.	**Name**	**Specs**	**Investigators**
GMD flasks	Glass whole-air sampling flasks	halocarbons, CO_2, alkanes	S. Montzka, C. Warneke (NOAA)
TDL H_2O and WVSS	tunable diode laser water vapor		NOAA AOC
PTRMS	proton transfer reaction mass spectrometer	acetonitrile, oxygenates, alkenes	J. de Gouw, C. Warneke (NOAA)
$NO/NO_2/NOy/O_3$	nitrogen oxides and ozone	10/30/15/100 pptv,<5%	T. Ryerson, J. Peischl (NOAA)
CO_2	carbon dioxide	0.1 ppmv	T. Ryerson, J. Peischl (NOAA)
CO	carbon monoxide	1.7 ppbv MDL, 5%	J. Holloway (NOAA)
PANs	peroxyacyl nitrates	1 pptv, 10%	J. Roberts (NOAA)
Halogens	Br_2, Cl_2, BrCl, BrO	CIMS I^-	A. Neuman (NOAA)
SO_2 CIMS, SO_2 UV	sulfur dioxide	CIMS SF_6^-, pulsed UV fluorescence	J. Nowak, J. Holloway (NOAA)

Combining Models and Measurements

Measurement	Simulation
In situ particle composition/size distribution, cloud condensation- and ice-nuclei spectra, cloud particle concentration, phase, size	Parcel model of cloud formation, ice nucleation and growth
In situ cloud dimension and up/downdraft velocity, cloud particle concentration, phase, size, solar and IR transmission/emission	Large eddy simulation (LES) with coupled cloud dynamics, microphysics, radiation in 3D Eulerian framework
In-situ particle composition/size distribution near and below cloud. Surface measurements of soot concentration in newly fallen snow	LES with in- and below-cloud aerosol scavenging
Gas phase chlorine compounds, sea salt aerosol chemistry, actinic fluxes	Parcel model with heterogeneous chemistry

...+ comparisons with remote sensing at Barrow

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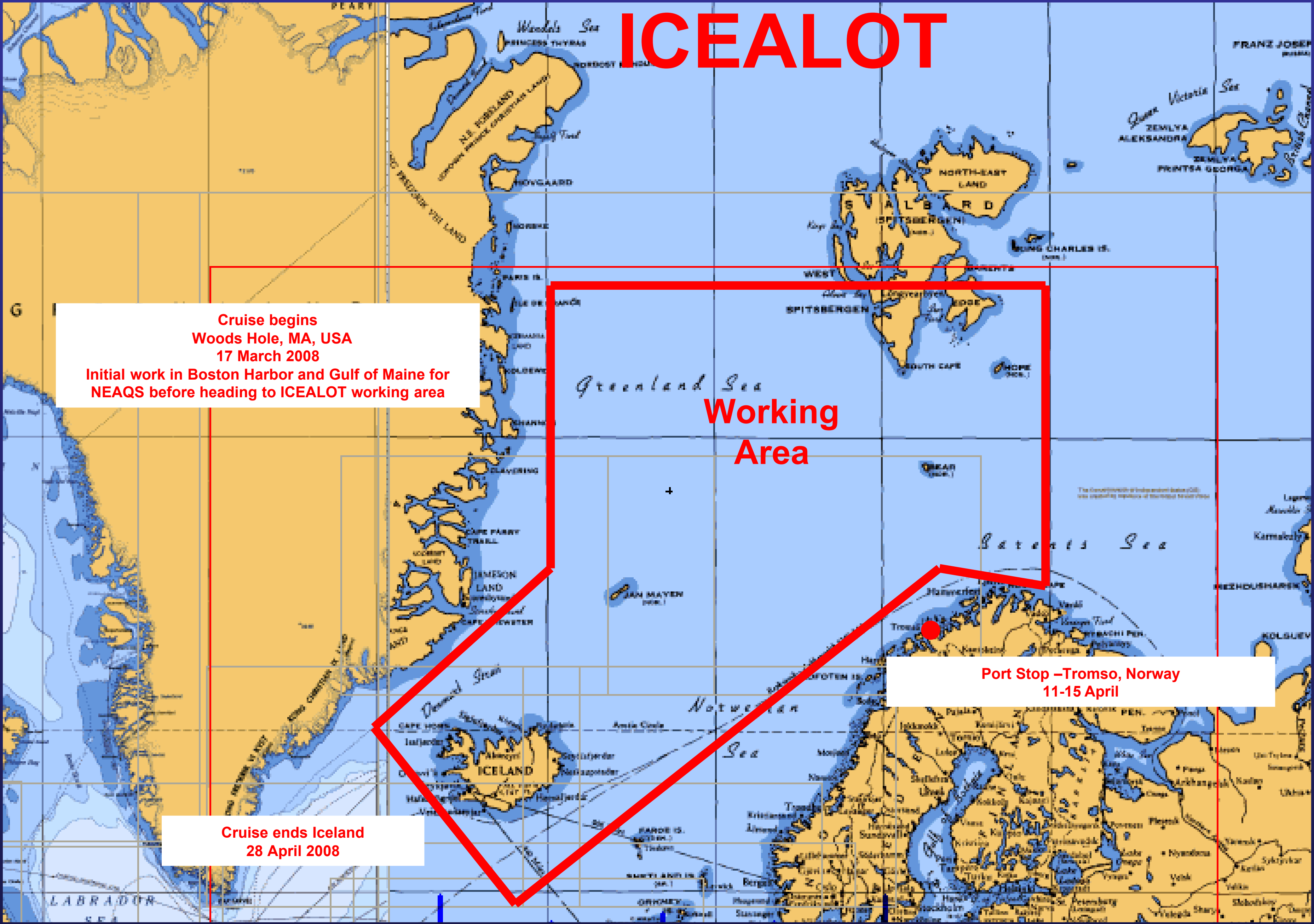
ICEALOT



Working Area

Cruise begins
Woods Hole, MA, USA
17 March 2008
Initial work in Boston Harbor and Gulf of Maine for NEAQS before heading to ICEALOT working area

Port Stop –Tromso, Norway
11-15 April

Cruise ends Iceland
28 April 2008

ICEALOT 2008 Knorr Measurements

Leg 1 - Woods Hole to Tromso, March 17-April 12, 2008

Leg 2 - Tromso to Reykjavik, April 13-24, 2008

Parameter	**Method**	**Lab**	**PI**
Aerosol ionic composition	PILS-IC	PMEL	Quinn
Aerosol WSOC	PILS-TOC	PMEL	Quinn/Bates
Aerosol size and composition	Quad- AMS	PMEL	Bates
Aerosol size and composition	ToF - AMS	Aerodyne	Worsnop
Single particle (180-3000nm Dp) aerosol size, composition (mixing state), and light scattering	ATOFMS	UCSD	Prather
Aerosol functional groups	FTIR	SIO	Russell
Size resolved aerosol composition and mass,2 stage (sub/super micron) & 7 stage at 60% RH	Impactors (IC, XRF and thermal optical OC/EC, total gravimetric weight)	PMEL	Quinn/Bates

Total and sub-micron aerosol scattering & backscattering (450, 550 and 700 nm) at 60% RH	TSI 3563 nephelometers (2)	PMEL	Quinn
Total and sub-micron aerosol absorption (450, 550, 700 nm) dry	Radiance Research PSAPs (2)	PMEL	Quinn
Aerosol light scattering hygroscopic growth	Twin TSI 3563 nephelometers	UW	Covert
Aerosol hygroscopic growth	HTDMA	Univ. Helsinki	Kulmala
Total and Sub-micron aerosol extinction, aerosol extinction hygroscopic growth	Cavity ring-down spect.	ESRL	Ravishankara
Sub-micron aerosol absorption	Photo acoustic	ESRL	Ravishankara
Aerosol number	CNC (TSI 3010, 3025)	UW/PMEL	Covert/Bates
Aerosol size distribution	DMA and APS	UW/PMEL	Covert/Bates
Non-volatile aerosol size distribution	SMPS (2) one with heated inlet	UW/PMEL	Covert/Bates
CCN	DMT	PMEL	Quinn

Atmospheric ion clusters and atmospheric nucleation	AIS	Univ. Helsinki	Kulmala
Cloud liquid water path	Microwave radiometer	ESRL	Fairall
Cloud droplet effective radius	Cloud radar	ESRL	Fairall
Radiative fluxes	Spectral radiometer	CU	Pilewski
Aerosol optical depth	Microtops	PMEL	Quinn
Aerosol vertical profiles	Micropulse lidar	UNH	Talbot
Photolysis rates (JNO2, JNO3, JO-1D)	Filter radiometer	ESRL	Lerner
Ozone	UV absorbance	ESRL	Williams
Ozone	UV absorbance	PMEL	Johnson
Ozone	NO chemiluminescence	ESRL	Williams
Carbon monoxide	UV fluorescence (AeroLaser)	ESRL	Lerner
Carbon dioxide	Non-dispersive IR	ESRL	Lerner
Water vapor	Capacitance probe	ESRL	Lerner
Sulfur dioxide	Pulsed fluorescence	ESRL	Lerner
Sulfur dioxide	Pulsed fluorescence	PMEL	Bates

Nitric oxide	Chemiluminescence	ESRL	Lerner
Nitrogen dioxide	Photolysis cell	ESRL	Lerner
Total nitrogen oxides	Au tube reduction	ESRL	Williams
PANs	GC/ECD	ESRL	Roberts
Alkyl nitrates, hydrocarbons	GC/MS	ESRL	Kuster
NO3/N2O5	Cavity ring-down spect.	ESRL	Brown
Acyl peroxy nitrates, ClNO2	CIMS	UW	Thornton
Particulate and gaseous persistent organic pollutants	GCMS	URI	Lohmann
Radon	Radon gas decay	PMEL	Johnson
Seawater and atmospheric pCO2	Non-dispersive IR	AOML	Wanninkhof
Seawater DMS	S chemiluminesence	PMEL	Bates/Johnson

Surface seawater primary production and respiration, O2, POC, PON, PIC, TOC, Chlorophyll a, nutrients, plankton cell biomass	O2 incubations, flow cytometry, and std techniques	Bigelow	Matrai
Temp/RH profiles	Sondes	ESRL	White
Turbulent fluxes	Bow-mounted EC flux package	ESRL	Fairall
High resolution turbulence	Mini-sodar	ESRL	Fairall
Meteorological forecasting	Flexpart	NILU	Burkhart
Data and systems management	PCs; Ship's LAN; e-mail; ftp	PMEL	Johnson
Data and systems management	Macs; PCs; e-mail; ftp	ESRL	Murphy