High summertime aerosol loading in the Arctic: sources and radiative effects

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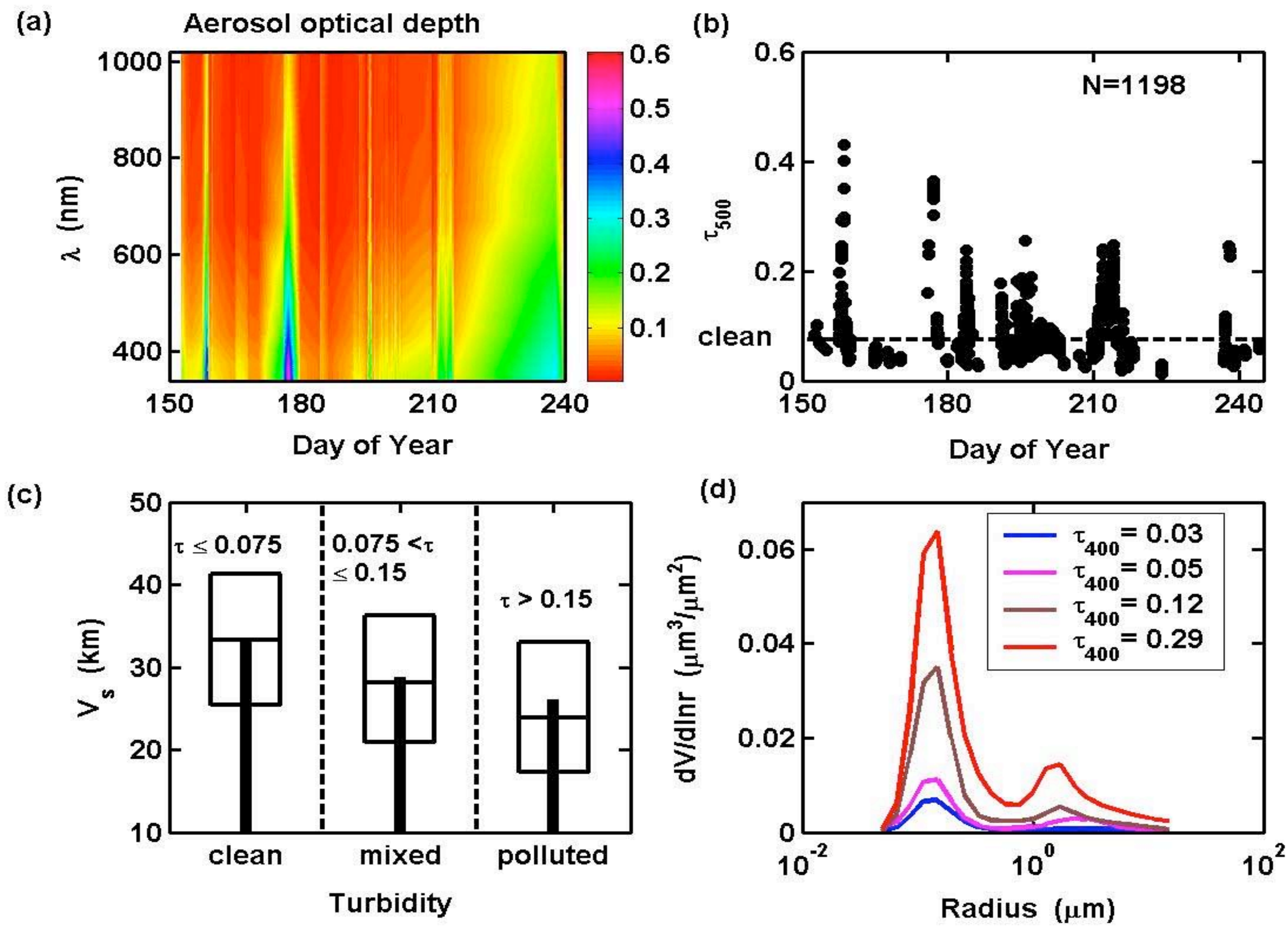
Current issues regarding Arctic summer aerosols

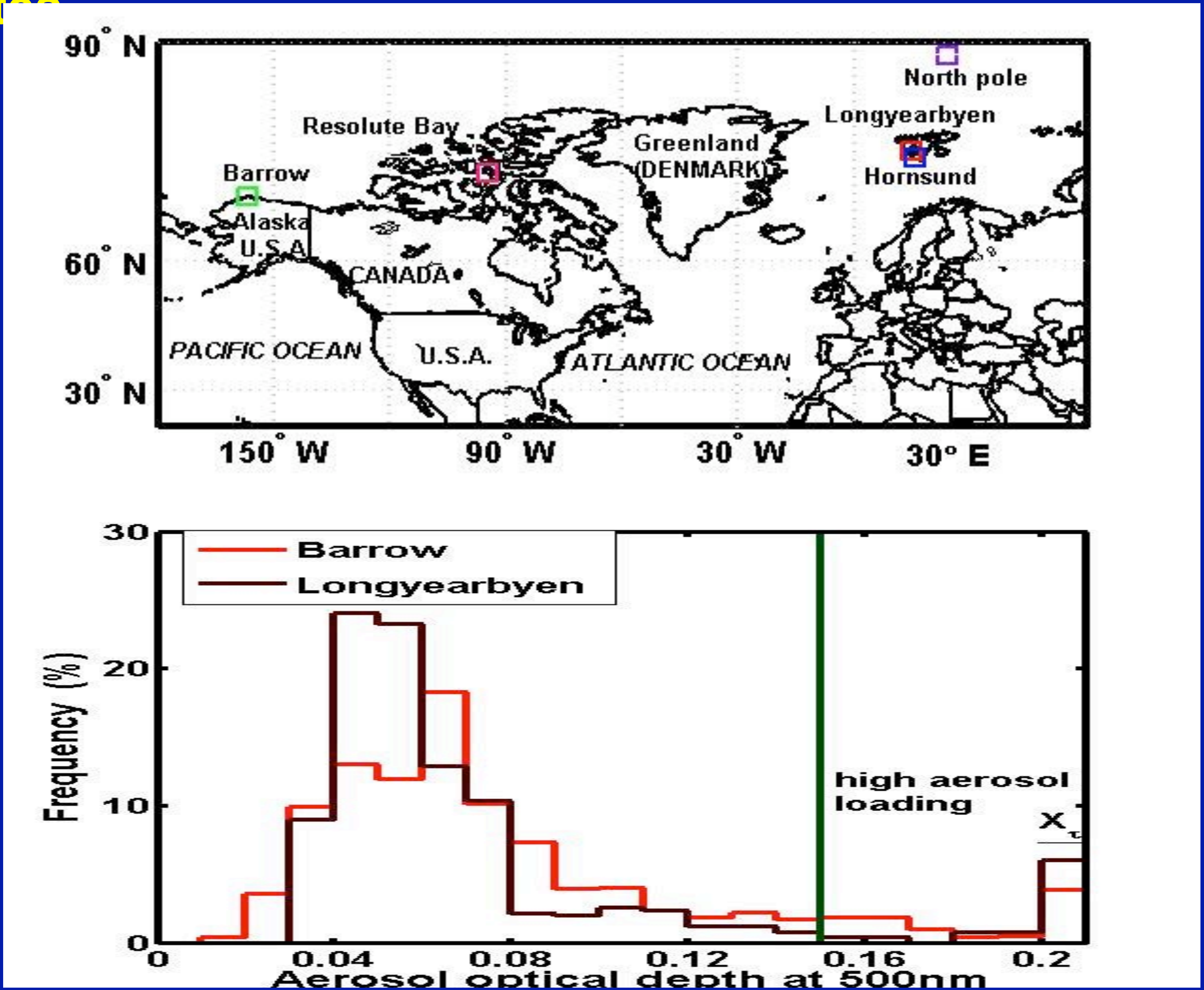
- θ There are still relatively few studies on Arctic summertime aerosols
- θ The magnitude and sign of radiative forcing by Arctic summer aerosols are still currently not well known
- θ Does pollution play any role in the Arctic climate during summer ?
- θ If so, to what extent ? What potential environmental effects could result from a summer pollution episode?

Alaskan Arctic

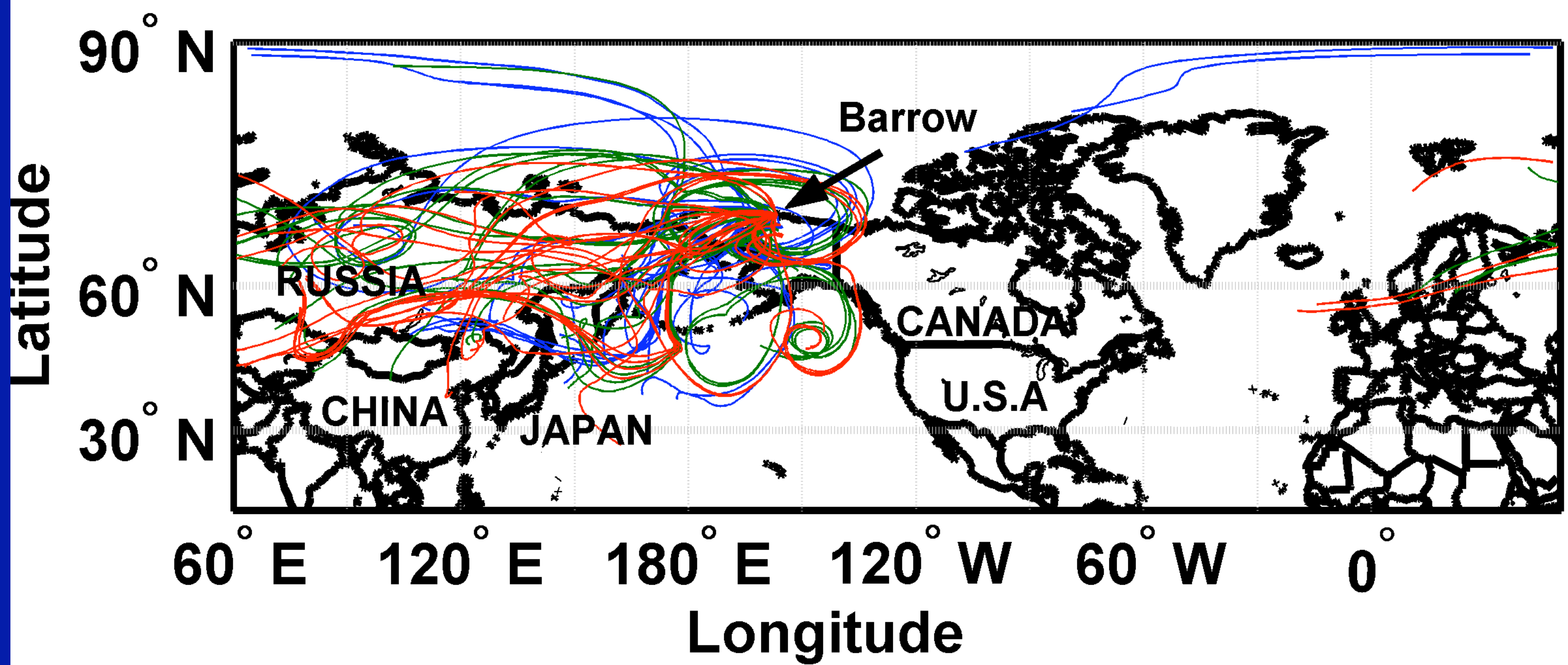
Summertime atmospheric measurements made at Barrow



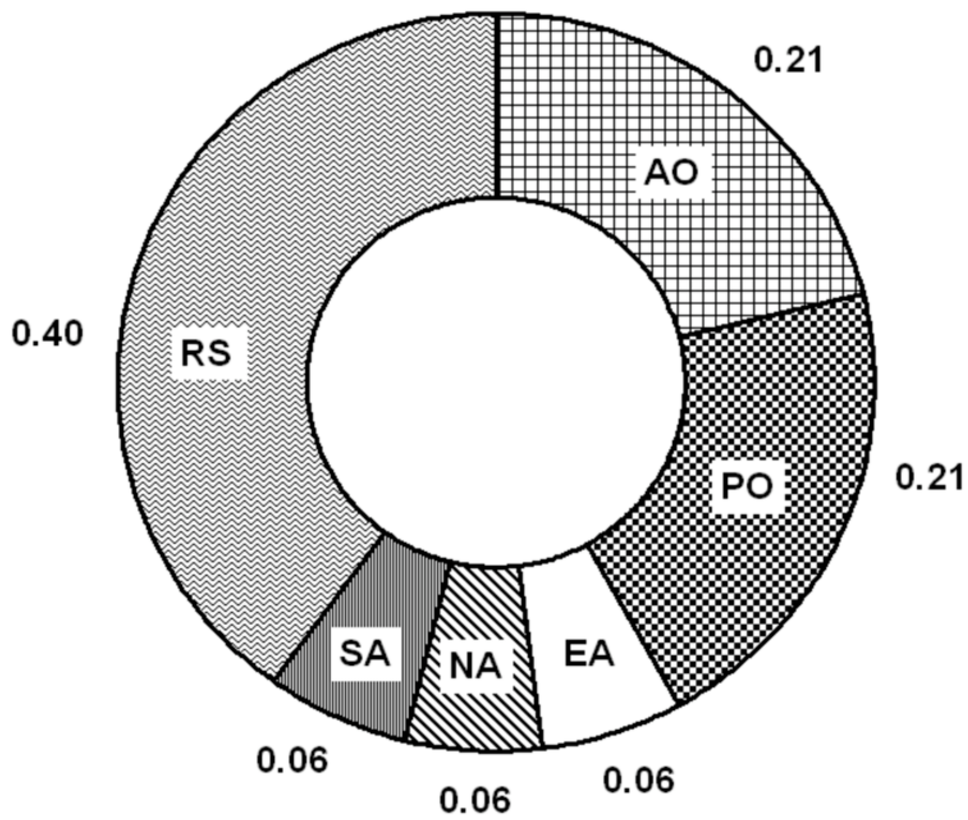
High aerosol loading also present at other Arctic sites



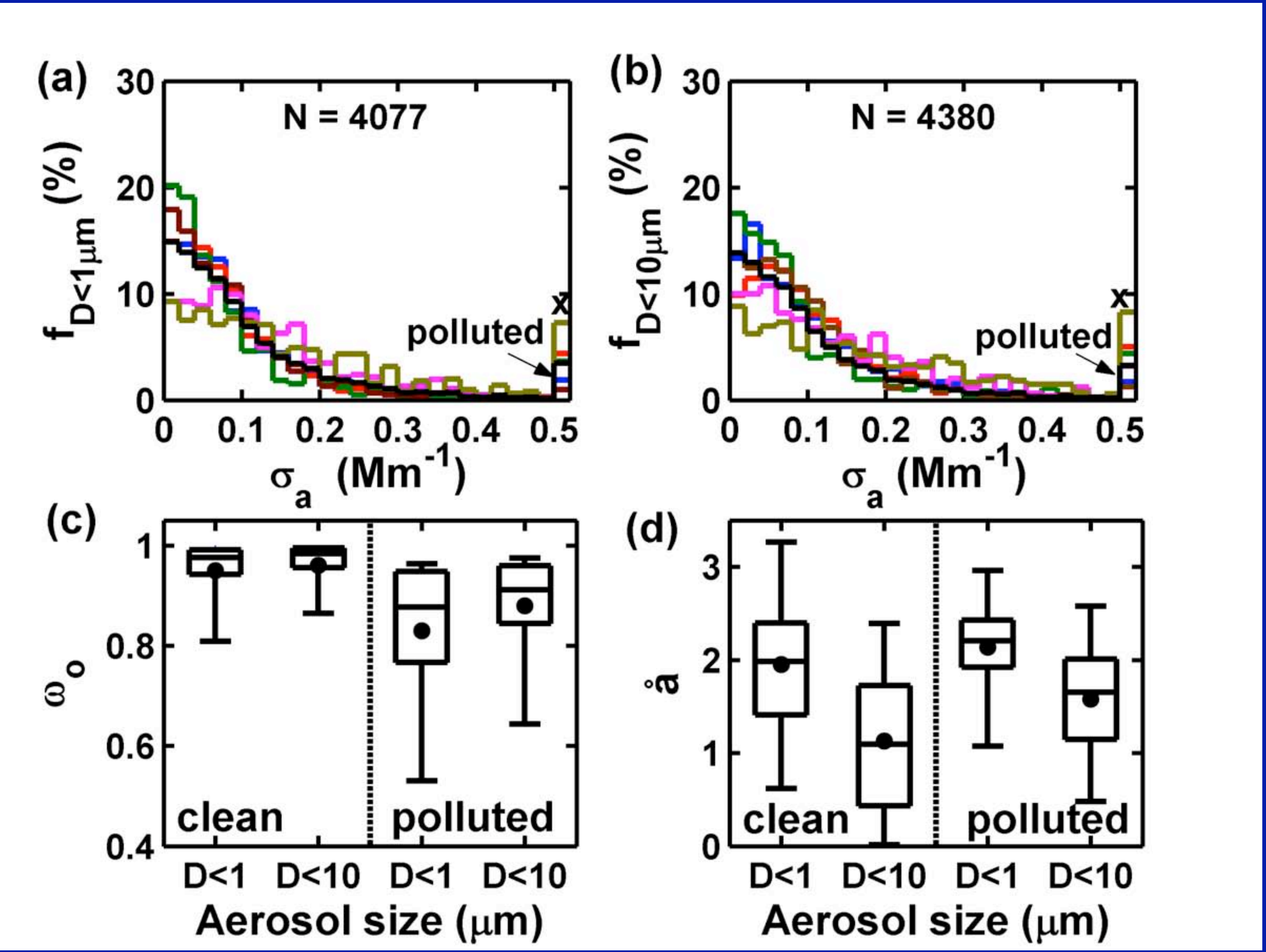
High altitude back trajectories for pollution periods



Potential source regions



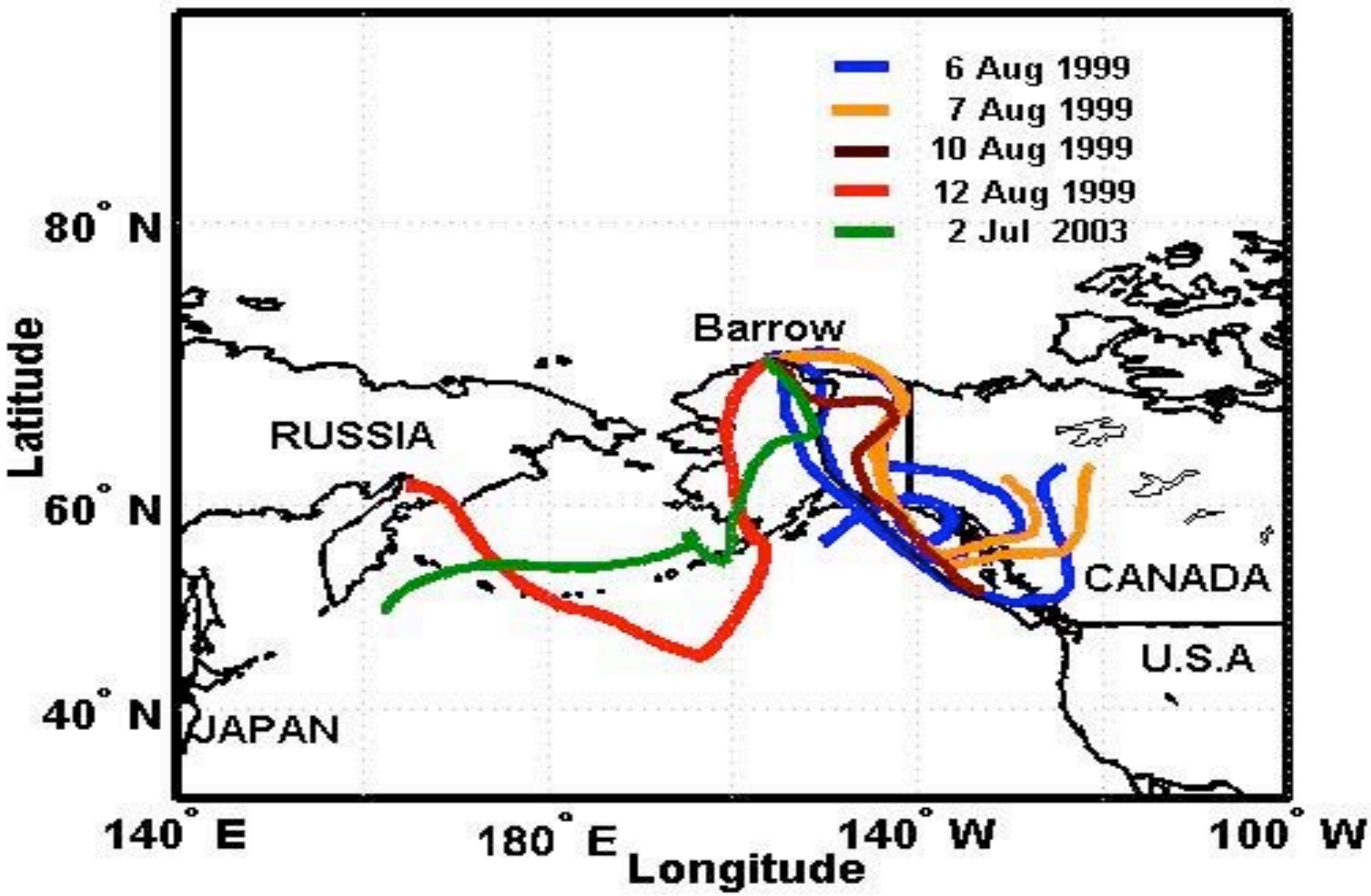
Presence of absorbing aerosols in the Arctic summer



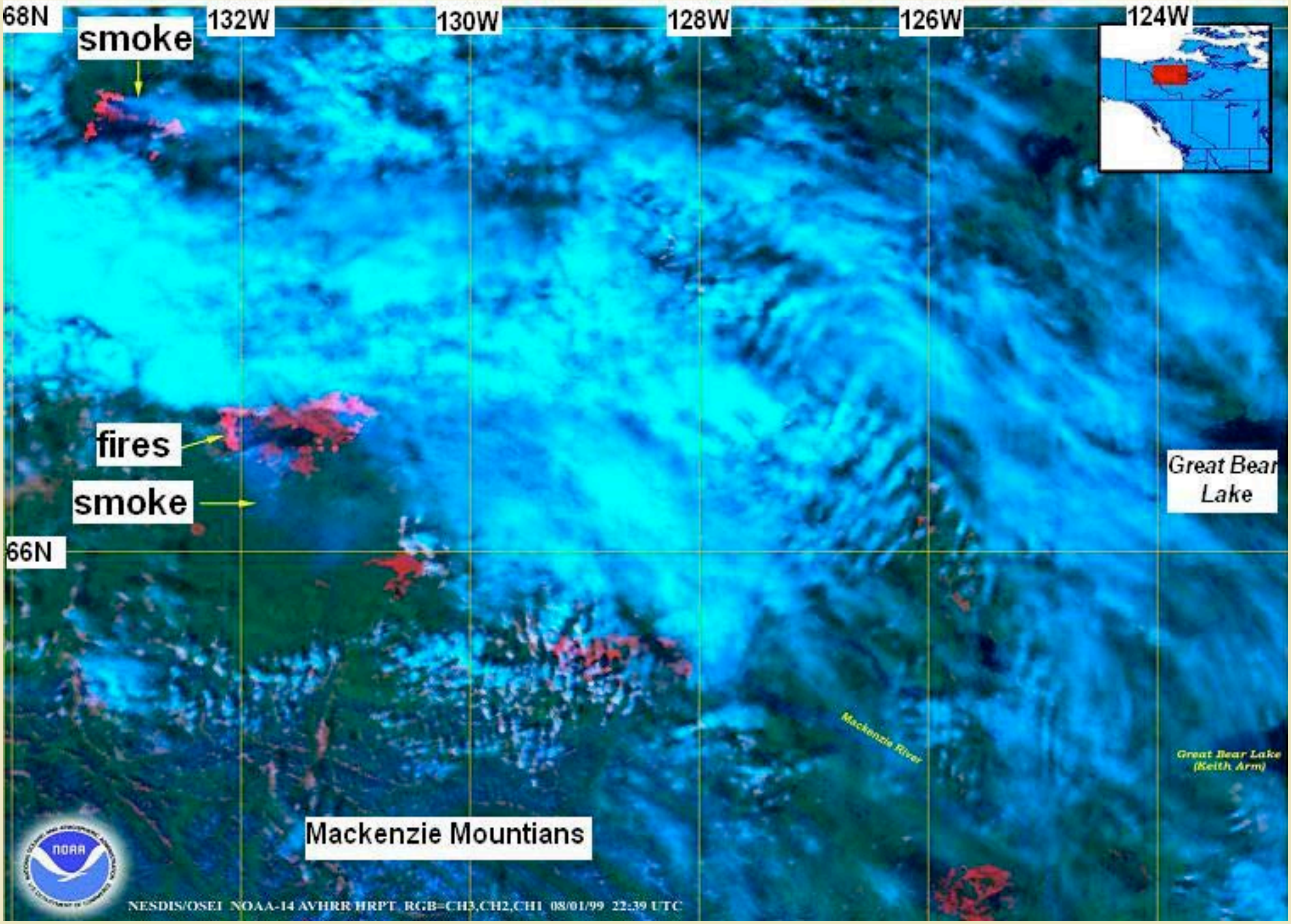
Aerosol Chemistry during selected Episodes

Event date	Max σ_a (Mm^{-1})	Ratio of polluted to clean conditions	
		K^+	Mg^{+2}
19 Jul 1998	1.16	2.4	3.0
20 Jul 1998	1.02	5.4	8.9
02 Aug 1999	1.11	2.4	3.0
06 Aug 1999	2.94	12.0	19.3
07 Aug 1999	1.60	12.0	19.3
10 Aug 1999	4.62	3.6	1.5
12 Aug 1999	2.35	3.6	1.5
23 Jul 2001	1.01	1.6	<1.0

8-day back trajectories for days with the highest light absorption coefficients



NOAA-14 AVHRR image for 22:39 UTC August 1, 1999



Potential Implications: Direct Radiative Effect

$\omega_c = \{2\alpha/[\beta\ (1-\alpha)^2+2\alpha]\}$

Where ω_c is the critical single scattering albedo, β is the upscatter fraction and

α is the surface albedo

Radiative forcing index $\Delta\omega = \omega_0 - \omega_c$

Aerosol impact: cooling if $\Delta\omega > 0$

warming otherwise

Radiative forcing index $\Delta\omega$ as a function of surface albedo for very absorbing aerosols $\Delta\omega_{abs}$ (with ω_o <0.88) and scattering aerosols $\Delta\omega_{sca}$ (with $\omega_o > 0.95$)

Measured surface albedo (%)	Nα (%)	$\Delta\omega_{abs}$	$\Delta\omega_{sca}$	$\Delta\omega_{abs} - \Delta\omega_{sca}$
$\alpha < 25$	71	0.23±0.17	0.38±0.14	-0.15
$25 < \alpha < 50$	10	0.0080±0.08	0.12±0.055	-0.11
$50 < \alpha < 75$	13	-0.24±0.11	0.0033±0.019	-0.24
$75 < \alpha < 100$	6	-0.24±0.078	-0.033±0.011	-0.21

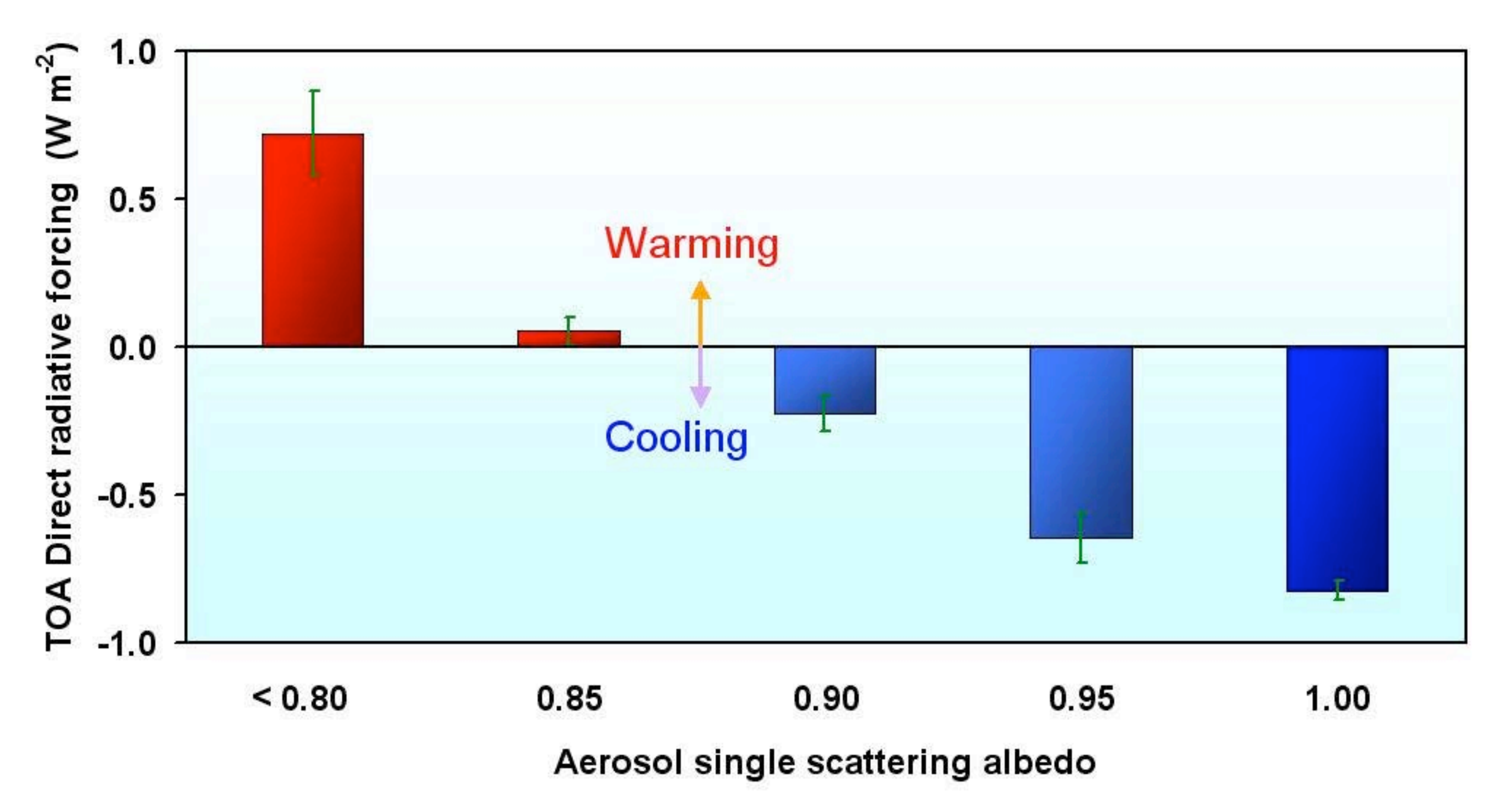
The top of the atmosphere aerosol direct radiative forcing

$$\Delta F^{TOA} = -DS_o T^2_{at}(1-A_c)\omega_o\beta\tau\{(1-\alpha)^2 - (2\alpha/\beta)[(1/\omega_o)-1]$$

- Haywood and Shine [1995]

Where D is the fractional day length, T_{at} is the atmospheric transmission and A_c is fractional cloud amount

Summer TOA direct radiative forcing as a function of aerosol single scattering albedo



Aerosol radiative forcing at the surface

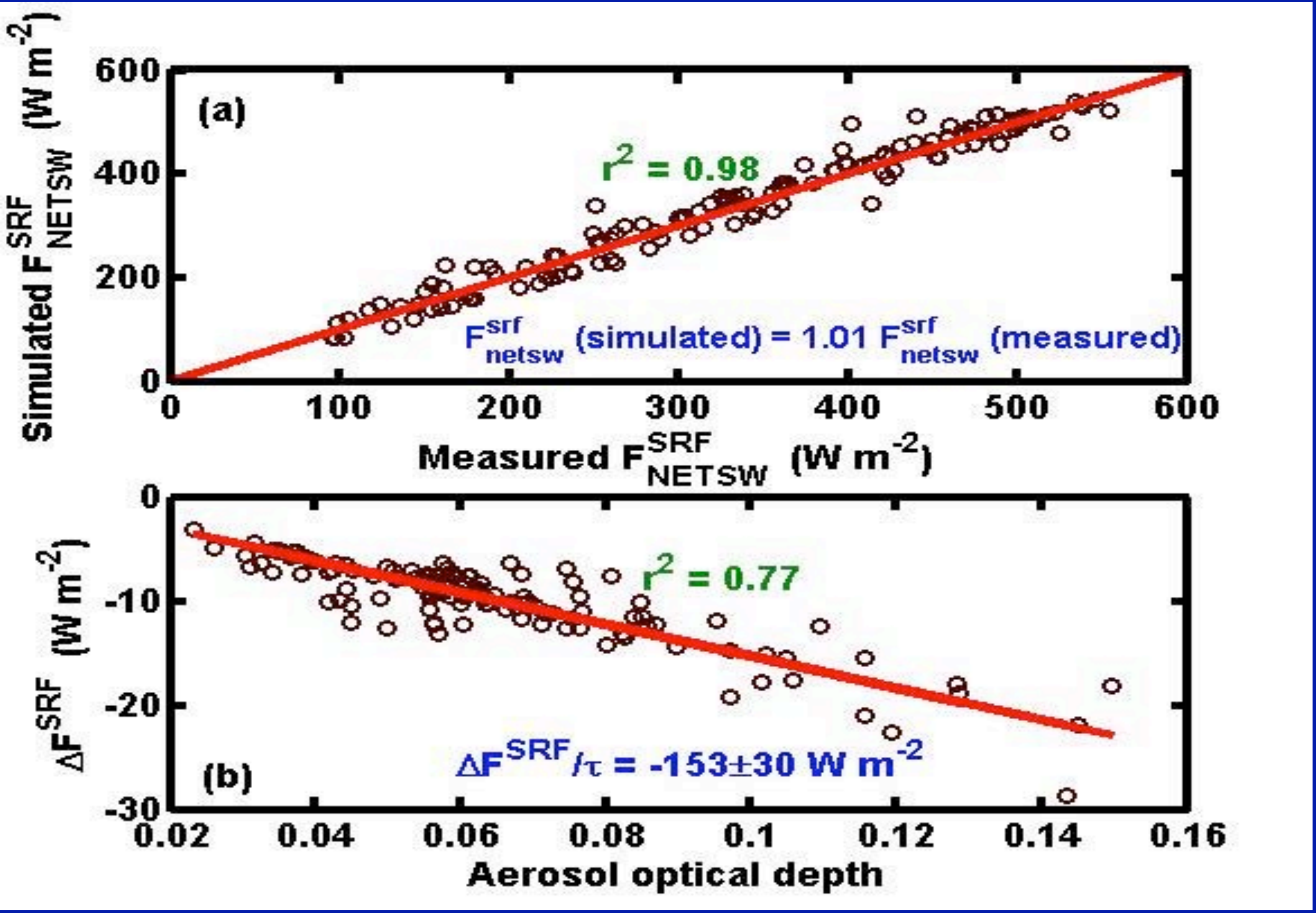
$$\Delta F^{SRF} = F_{NETSW}^{SRF} - F_{NETSW}^{SRF(0)}$$

where F_{NETSW}^{SRF} is net shortwave flux with atmospheric aerosol

and $F_{NETSW}^{SRF(0)}$ is the aerosol-free net shortwave flux

$F_{NETSW}^{SRF(0)}$ obtained from a radiative transfer model- Richiazzi et al. (1998)

Surface aerosol forcing



Conclusion

- Although the Arctic generally exhibit low aerosol burden in the summer, cases of high loading occur 10±4 days.
- The frequency of transport from Russia is dominant for observed pollution cases, with 45% of the air mass trajectories originating from this sector.
- The days with the highest levels of aerosol absorption are associated with smoke from wild fires.
- Although a warming aerosol effect is facilitated by a bright surface and low aerosol single scattering albedo, we observe that even with a low surface albedo in the summer, ΔF^{TOA} turns positive for $\omega_o \leq 0.85$.
- The surface radiative forcing ranges between –3.2 W m^{-2} and -29 W m^{-2} for observed cases of aerosol optical depth.

What still needs to be done

- Additional measurements needed to:
- Further identify the chemical composition of summertime pollutants : What is the possibility of the presence of V, Mn, SO_4, Pb, Zn Cd, Cu?
- Extend study to other polar sites
- Investigate possible effects on clouds
- Integrating these observations into climate and air quality models to help improve their representations of Arctic summertime conditions

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