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OPTICAL PROPERTIES OF ARCTIC AEROSOL IN SPRING BASED ON SKY-RADIOMETER AND MICRO-PULSE LIDAR MEASUREMENTS AT NY-ALESUND, SVALBARD

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Introduction

National Institute of Polar Research (NIPR) promotes atmospheric research in both polar regions. Atmospheric research by NIPR includes ground-based remote-sensing of aerosol and clouds for long-term and continuous basis measurements at Rabben Station in Ny-Alesund, Svalbard (78.9N, 11.9E). A sky-radiometer (Prede, POM-02) and a micro-pulse lidar (MPL, NASA-upgraded SESI model) have been operated at Ny-Alesund, Svalbard to observe aerosol optical properties and vertical structures.

Tropospheric aerosol has a potential to change the global climate by direct and indirect effects on the energy balance in the planetary atmosphere-surface system. Optical properties of aerosol are essential parameters for estimating the aerosol direct effect.

Extremely high aerosol optical thickness (AOT) was recorded in spring 2006. The high AOT event has been analyzed and was found to be caused by intrusion of fire smoke mainly from crop fields in Eastern Europe (Myhre et al, 2007; Stohl et al, 2007; Treffeisen et al, 2007). In this paper, we will show results focusing on the aerosol optical properties inferred from sky-radiometer and MPL measurements in spring 2006 and 2007 including the 2006 Arctic smoke event.

References

Myhre, C.L. et al., 2007: Regional aerosol optical properties and radiative impact of the extreme smoke event in the European Arctic in spring 2006. *Atmos. Chem. Phys.*, **7**, 5899-5915.

Stohl, A. et al., 2007: Arctic smoke – record high air pollution levels in the European Arctic due to agricultural fires in Eastern Europe in spring 2006. *Atmos. Chem. Phys.*, **7**, 511-534.

Treffeisen, R. et al., 2007: Arctic smoke – aerosol characteristics during a record smoke event in the European Arctic and its radiative impact. *Atmos. Chem. Phys.*, **7**, 3035-3053.

Research objectives of ground-based aerosol/cloud remote sensing in the Arctic by NIPR

1. Climatology and variability of aerosol/cloud properties in the Arctic:
   # Aerosol optical properties, optical thickness, extinction profile
   # Aerosol size distribution, complex refractive index, single scattering albedo
   # Cloud (base) height, appearance frequency
2. Aerosol-cloud interaction:
   # Formation and dissipation processes of aerosol and clouds
   # Arctic haze and arctic stratus clouds
   # Difference of indirect effect between both polar regions

3. Contribution to international programs and global networks:
   # A unique site of SKYNET and MPLNET in the Arctic region
   # Ground validation of aerosol/cloud retrievals from satellite measurements
   # International projects for IPY; Polar-AOD, IASOA, POLARCAT, ARCTAS

Sky-radiometer, Prede POM-02

Specifications	
Wavelength	(315, 340, 380,) 400, 500, 675, 870, (940,) 1020, (1600, 2200) nm
Monochromator	Narrow-bandpass interference filter
FWHM of filter	3 nm for 315-ch, 10 nm for others
Detector	Silicon PIN photodiode
Elec. dynamic range	10^7
FOV angle	1 deg in full (2.4E-4 sr), nominal
Temperature control	Const. 20 ℃ (sensor unit)
Ambient environment	-30 to +20 ℃ (sensor unit) 0 to 35 ℃ (control unit)

Sky-radiometer operated at Rabben Station, Ny-Alesund, Svalbard since March 2000

Sky-radiometer Measurement (2006.3.28) and Inversion Result (SKYRAD.pack Ver. 4.2)

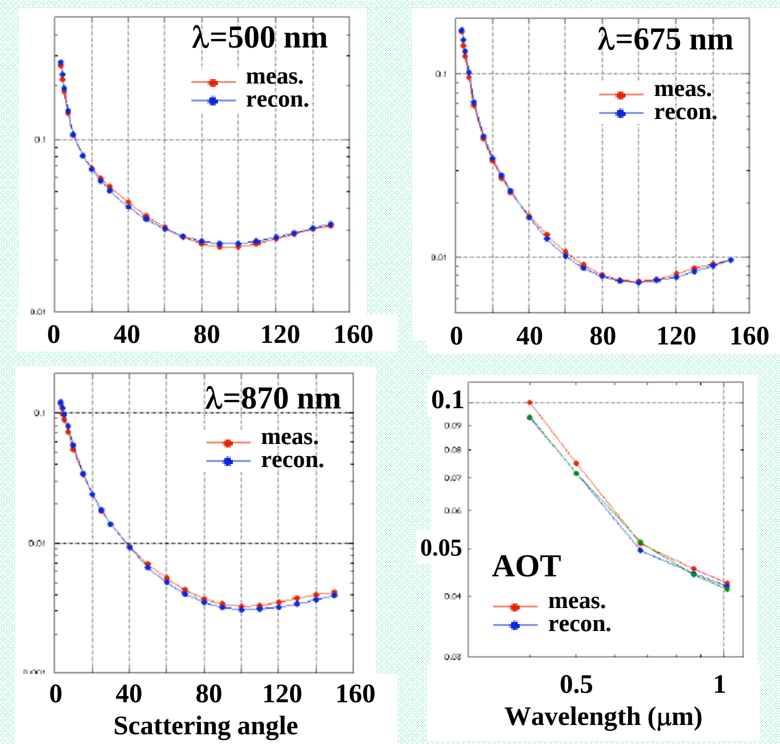
Sky-radiometry

Aerosol optical thickness (AOT): $\tau_A(\lambda)$

$$\tau_A(\lambda) = \int_{r_m}^{r_M} \pi r^2 Q_{\text{ext}}(x, \tilde{m}) n(r) \mathrm{d}r,$$

Single scattering phase function: $\beta_A(\Theta)$

$$\beta_A(\Theta) = \frac{\lambda^2}{2\pi} \int_{r_m}^{r_M} [i_1(\Theta, x, \tilde{m}) + i_2(\Theta, x, \tilde{m})] n(r) \mathrm{d}r,$$



Input data

AOT: direct solar attenuation, $= \tau_T - \tau_R - \tau_{O3}$

Scattered radiance: 3 – 70 deg, and larger

wavelength: 400, 500, 675, 870, 1020 nm

assumptions: A_s=0.5, O_3= 300 DU

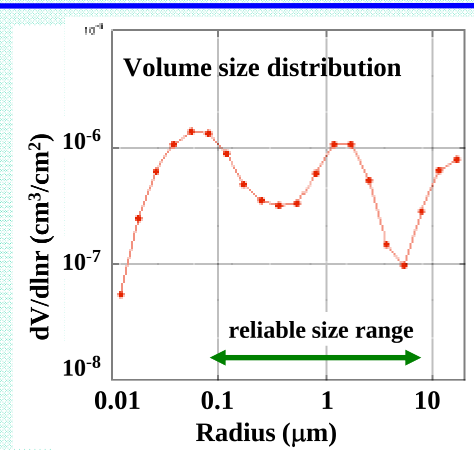
Output retrievals

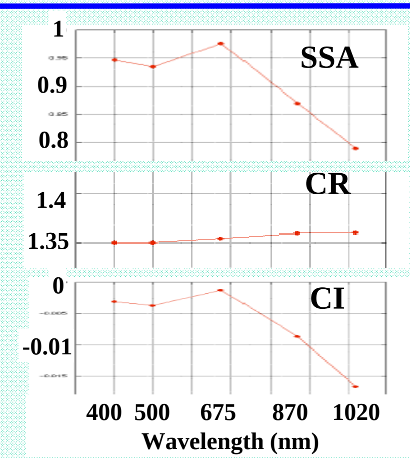
Volume size distribution

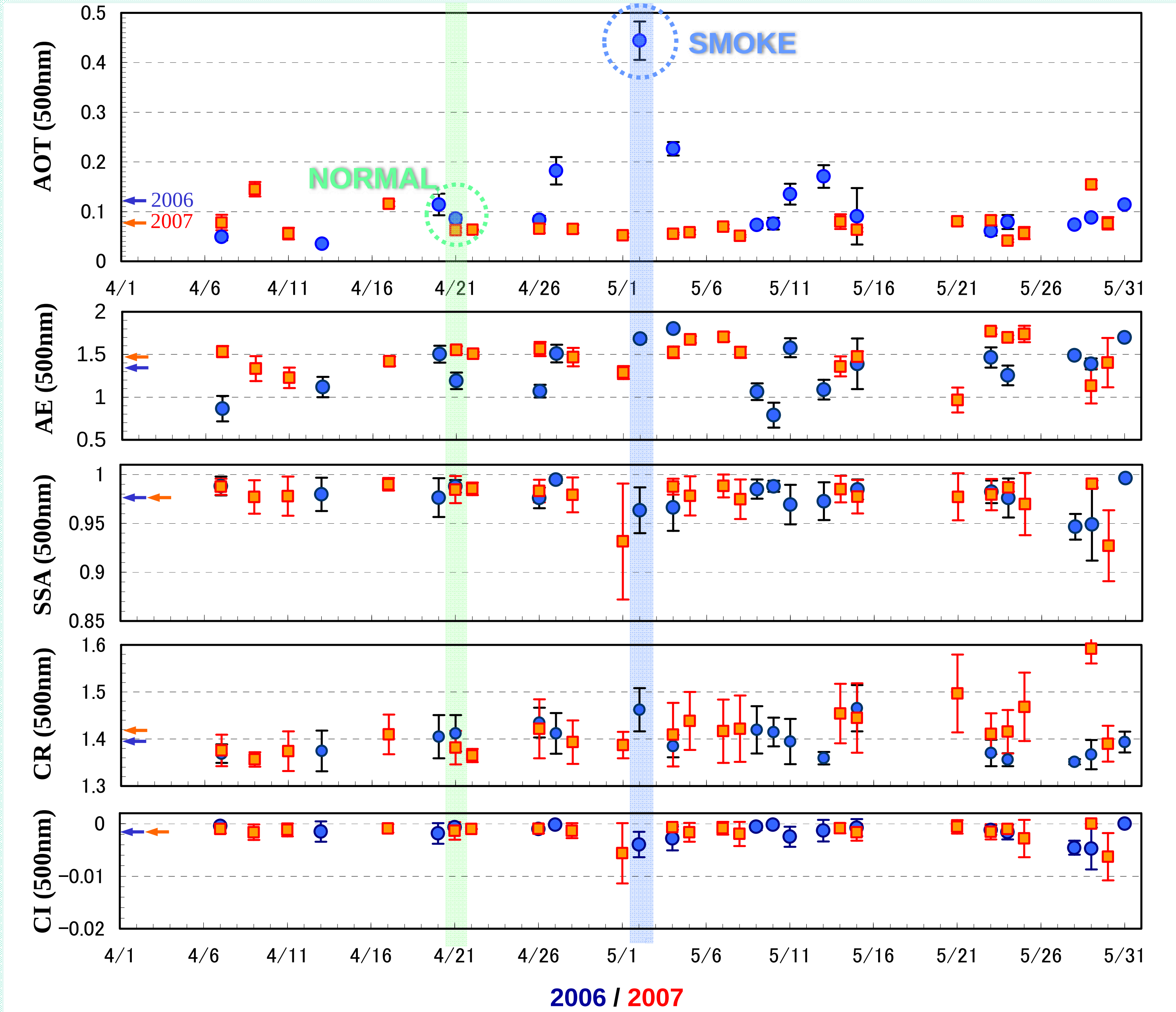
size range: r = 0.01 – 20 μm, 20 bins

Complex refractive index (CR, CI)

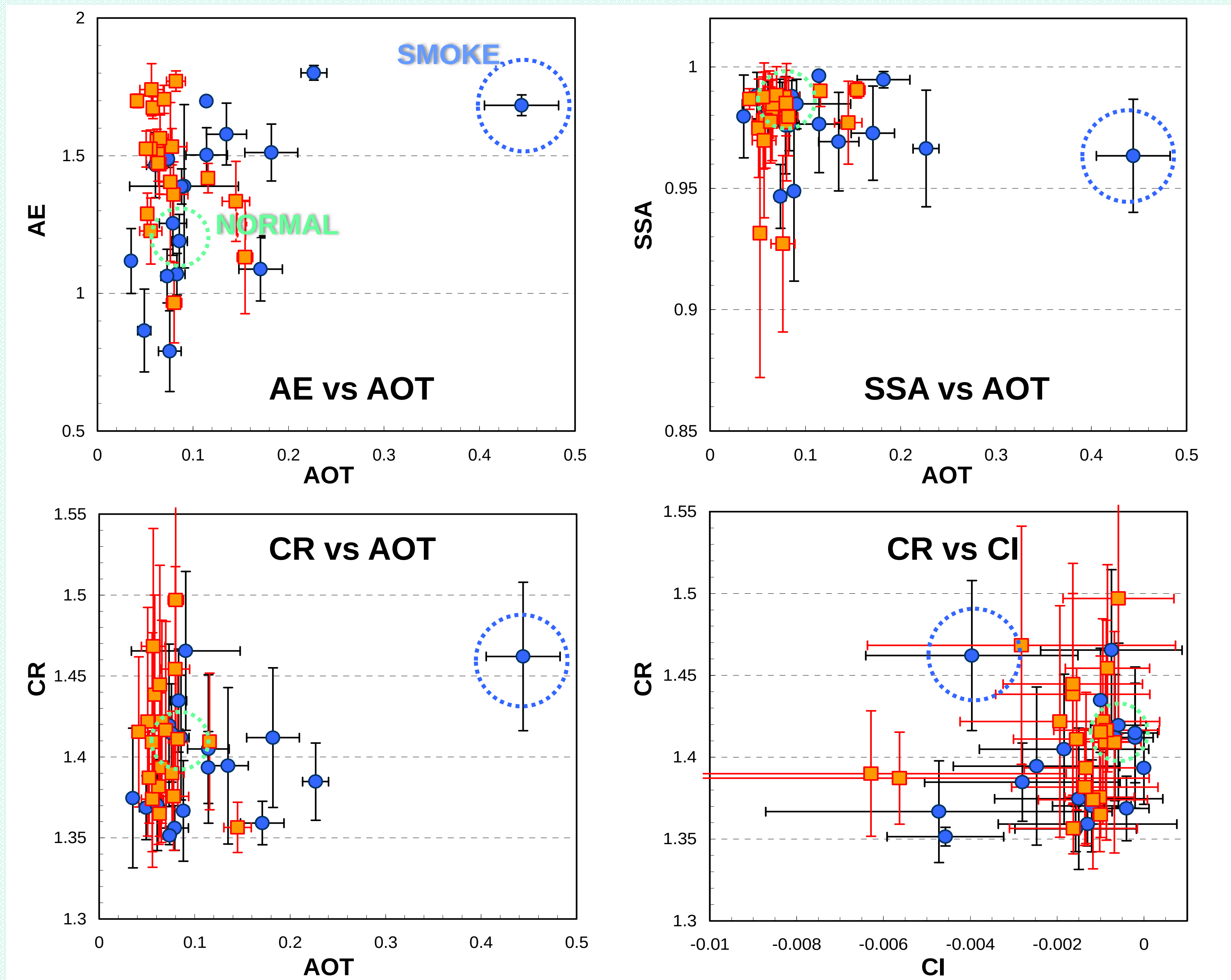
Single scattering albedo (SSA)



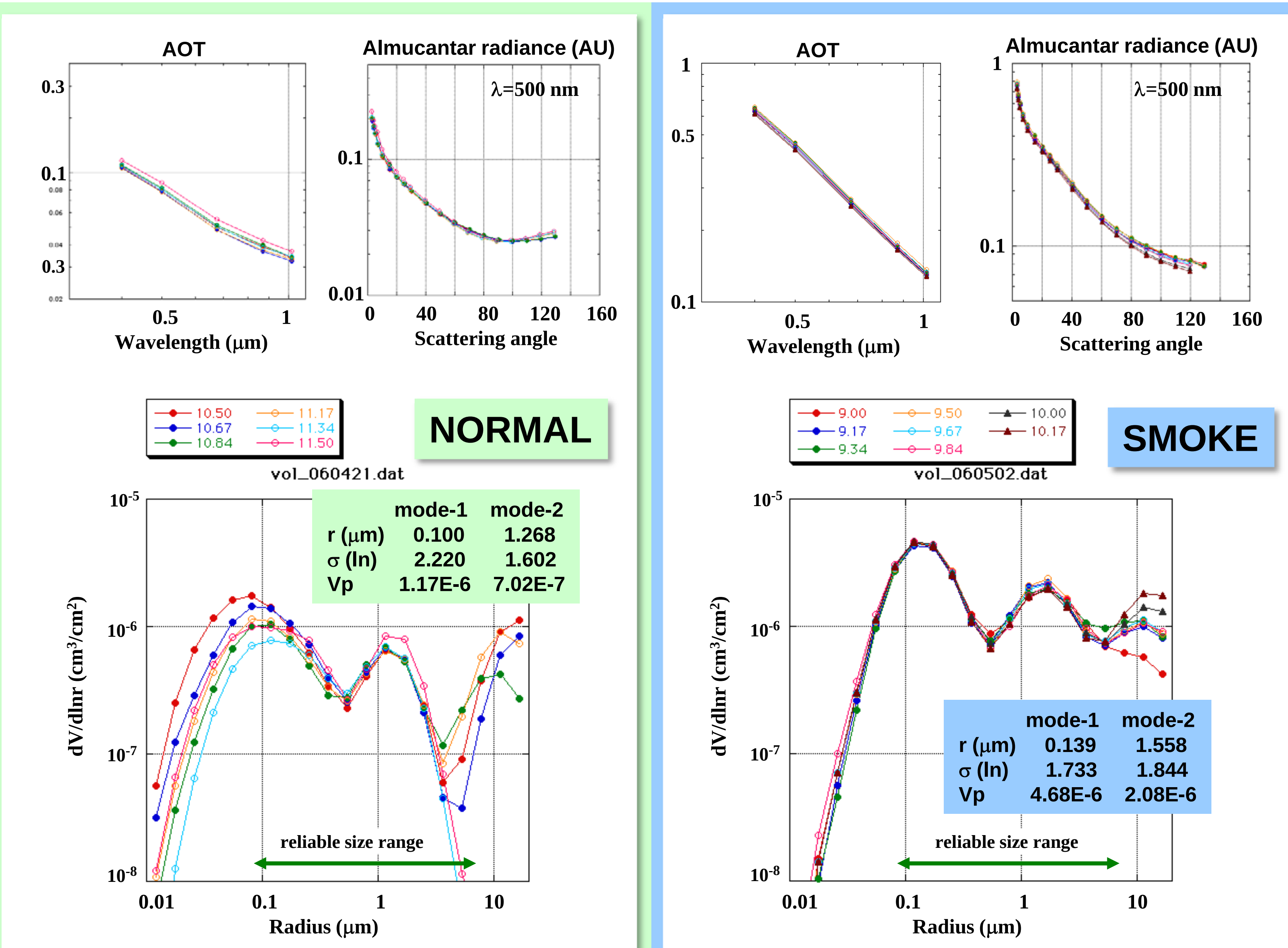




Temporal variations of aerosol optical properties in spring 2006 (blue) and 2007 (red), Ny-Alesund



Correlation plots for optical parameters obtained for spring 2006 (blue) and 2007 (red)

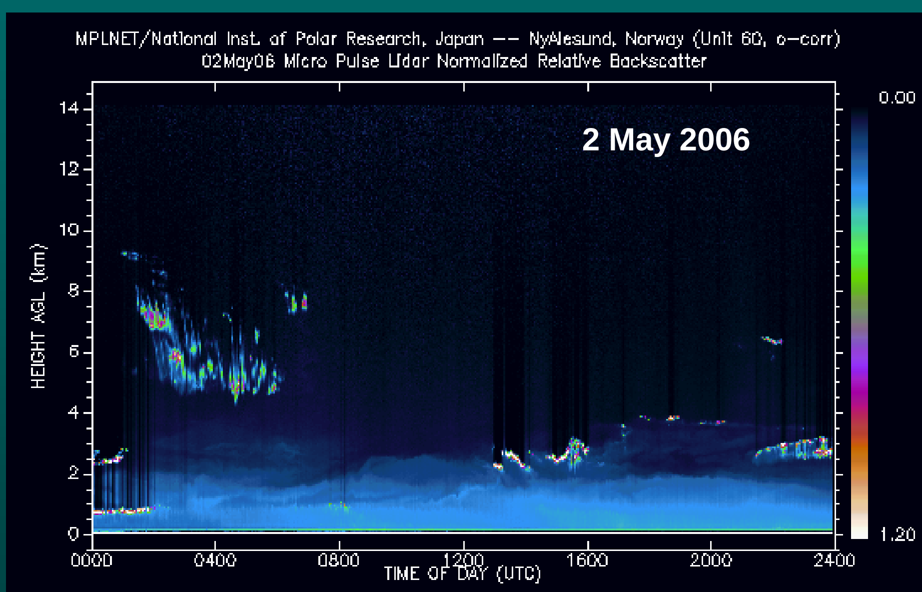


Volume size distribution (bottom) retrieved from sky-radiometer data (top) for normal state on April 21 (left) and for smoke event on May 2 (right), 2006.

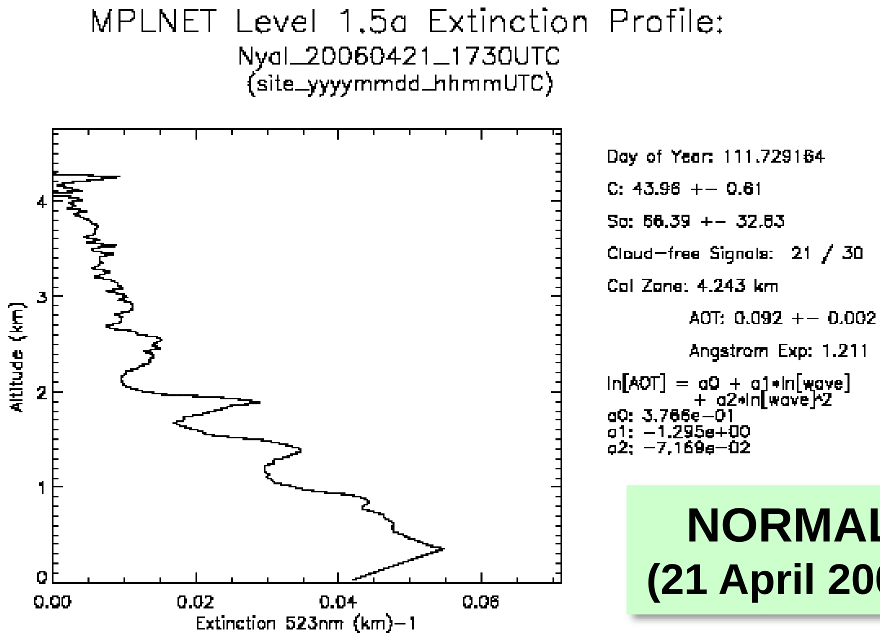
Micro-Pulse Lidar (MPL)

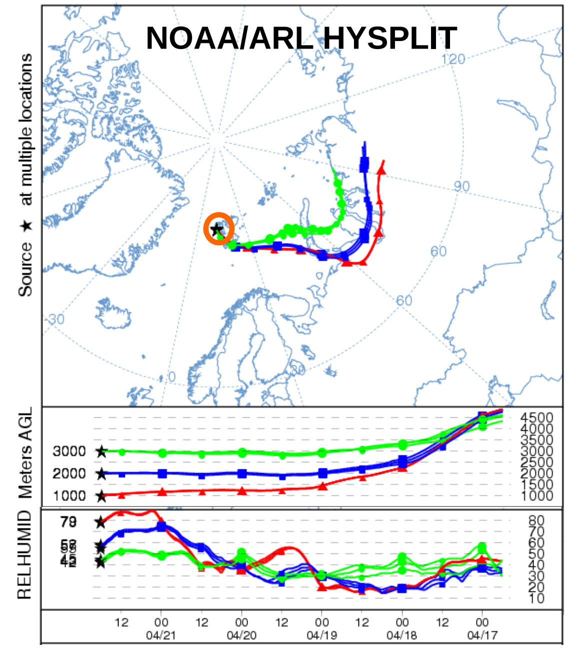
NASA-upgraded SESI Model

Specifications	
Laser	Diode-pumped Nd:YLF laser
Wavelength	523 nm
Pulse energy	8-10 μJ
Pulse frequency	2500 Hz
Detector	Single photon counting APD
Range resolution	30 m

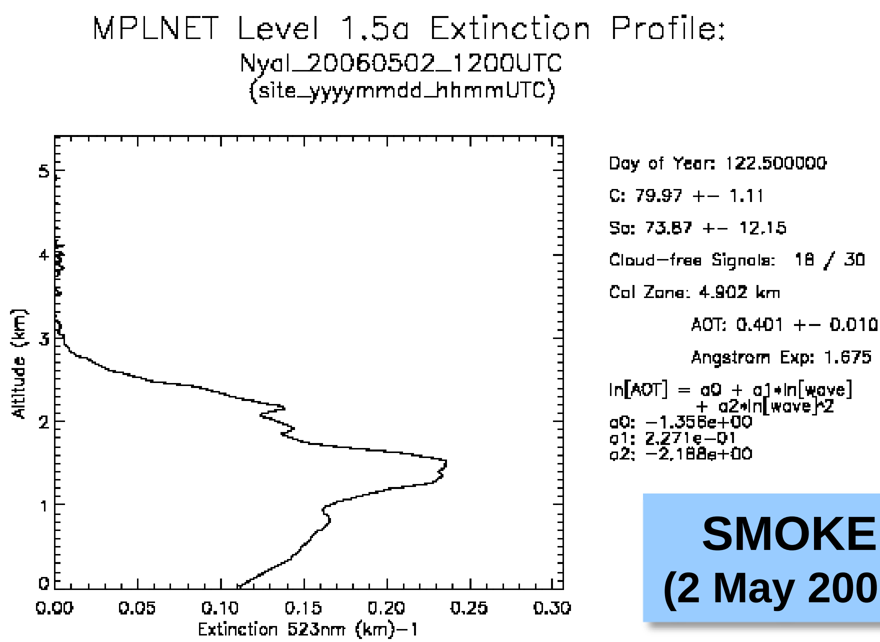


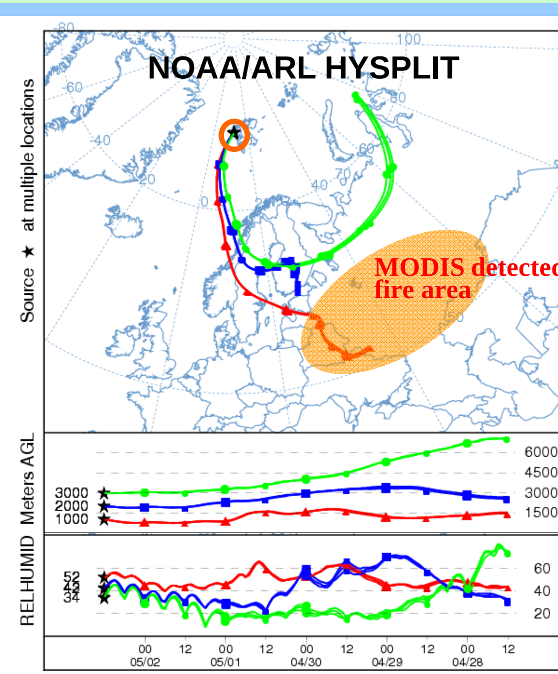
MPL operated at AWIPEV Station, Ny-Alesund, Svalbard since June 2003



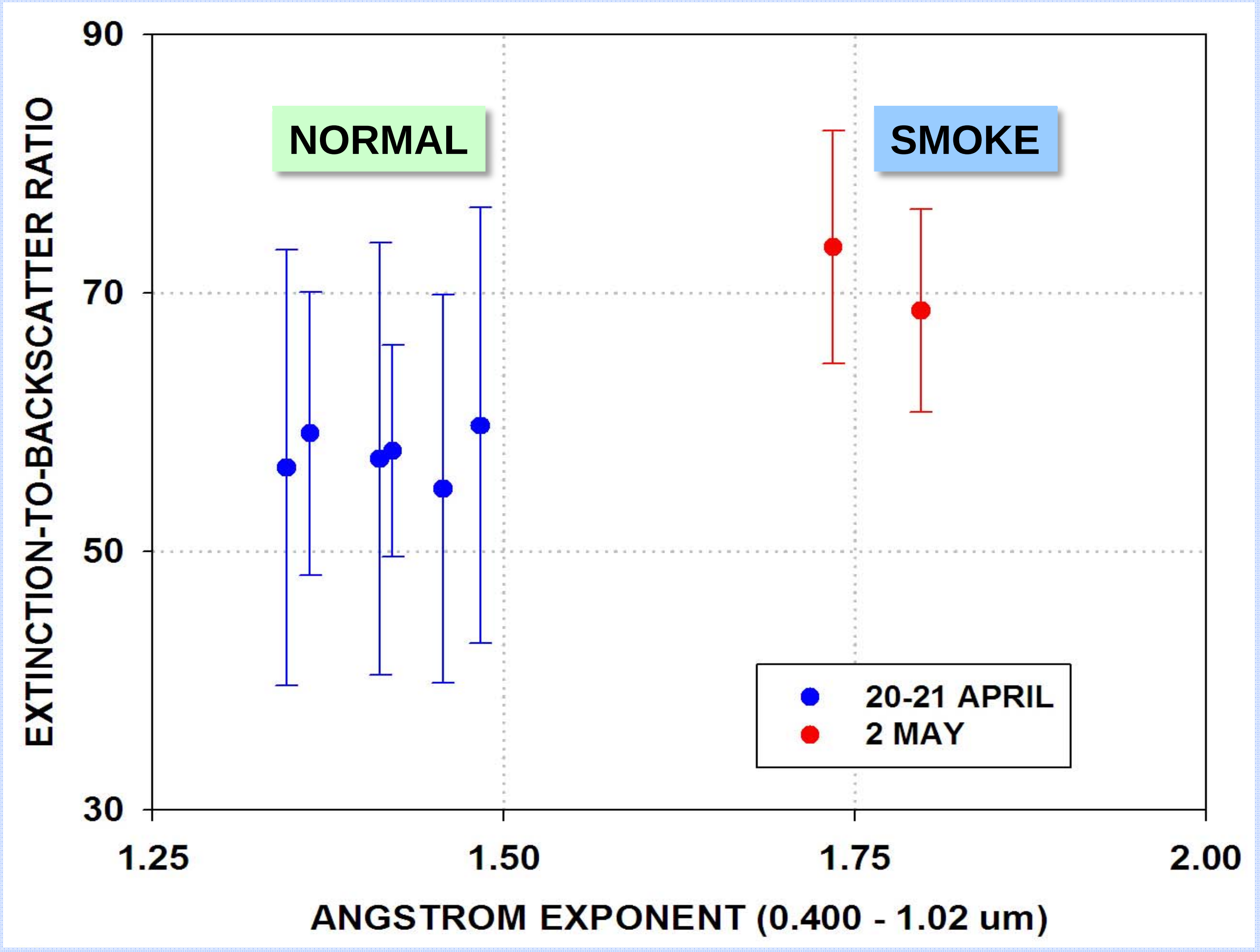


NORMAL
(21 April 2006)





SMOKE
(2 May 2006)



Extinction-to-backscatter ratio at λ=523nm estimated from MPL and Sky-radiometer measurements versus Angstrom exponent obtained for spectral AOTs.

Table 1 Aerosol optical parameter average values (avr) and standard deviation (std) for spring (April and May) of 2006 and 2007

		AOT	AE	SSA	CR	CI
2006	avr	0.121	1.330	0.977	1.397	-0.0017
	std	0.050	0.290	0.014	0.034	0.0015
2007	avr	0.075	1.470	0.977	1.420	-0.0017
	std	0.029	0.205	0.017	0.053	0.0015

Table 2 Comparison of normal state and smoke event in 2006

		AOT	AE	SSA	CR	CI
normal	avr	0.086	1.190	0.988	1.412	-0.0007
(4/21)	std	0.008	0.097	0.006	0.039	0.0005
smoke	avr	0.444	1.683	0.963	1.462	-0.0040
(5/2)	std	0.039	0.138	0.023	0.046	0.0024

Summary

1. Aerosol optical properties in Arctic spring have been investigated based on Sky-radiometer and Micro-Pulse Lidar (MPL) measurements performed in Ny-Alesund, Svalbard.
2. SKYRAD.pack Ver.4.2 inversion scheme was applied for obtaining volume size distribution, single scattering albedo (SSA), complex refractive index (CR, CI) as well as aerosol optical thickness (AOT) and Angstrom exponent (AE). Extinction vertical profile and extinction-to-backscatter ratio were examined by combined analysis with MPL and Sky-radiometer data.
3. From 2006 and 2007 measurements, average values of AOT, AE, SSA, CR, and CI for Arctic spring aerosols were obtained.
4. Aerosol optical properties for a high-turbid smoke event in early May 2006 well contrasted with those for normal state. The size distribution and complex refractive index of smoke aerosol on 2 May retrieved by SKYRAD analysis suggested that the smoke layer included organics origin aerosol and light absorbing particles additionally to sulfate and sea-salt particles that are dominant for normal state.

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