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Workshop on Aerosol Impact in the Environment: from Air Pollution to Climate Change

8 - 12 August 2011

Aerosol optical model under low and high atmosphere turbidity for West Siberia

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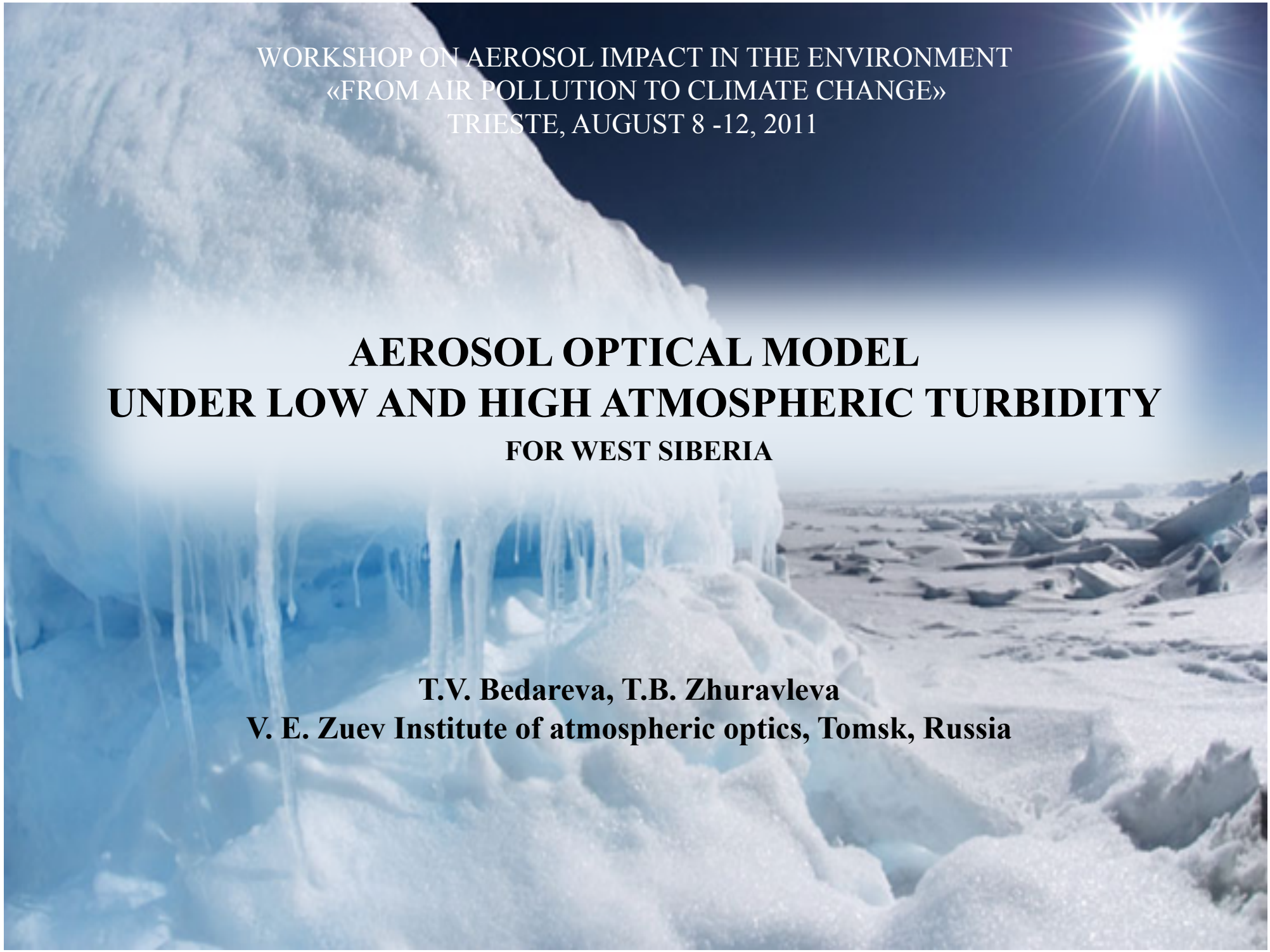

WORKSHOP ON AEROSOL IMPACT IN THE ENVIRONMENT
«FROM AIR POLLUTION TO CLIMATE CHANGE»
TRIESTE, AUGUST 8 -12, 2011

AEROSOL OPTICAL MODEL UNDER LOW AND HIGH ATMOSPHERIC TURBIDITY

FOR WEST SIBERIA

T.V. Bedareva, T.B. Zhuravleva
V. E. Zuev Institute of atmospheric optics, Tomsk, Russia

CONTENT

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- ❑ Introduction
- ❑ Retrieval algorithms / Description
- ❑ Aerosol absorption / Empirical assessments
  - Background cases vs. Model data
  - Biomass burning cases vs. AERONET *Level 2.0*
- ❑ Experimental base / Selection strategy
- ❑ Black carbon content and specific absorption

Region specifics / Tomsk

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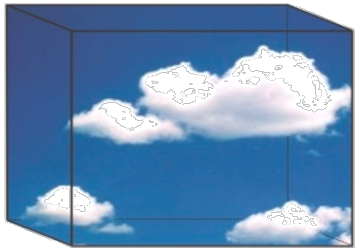
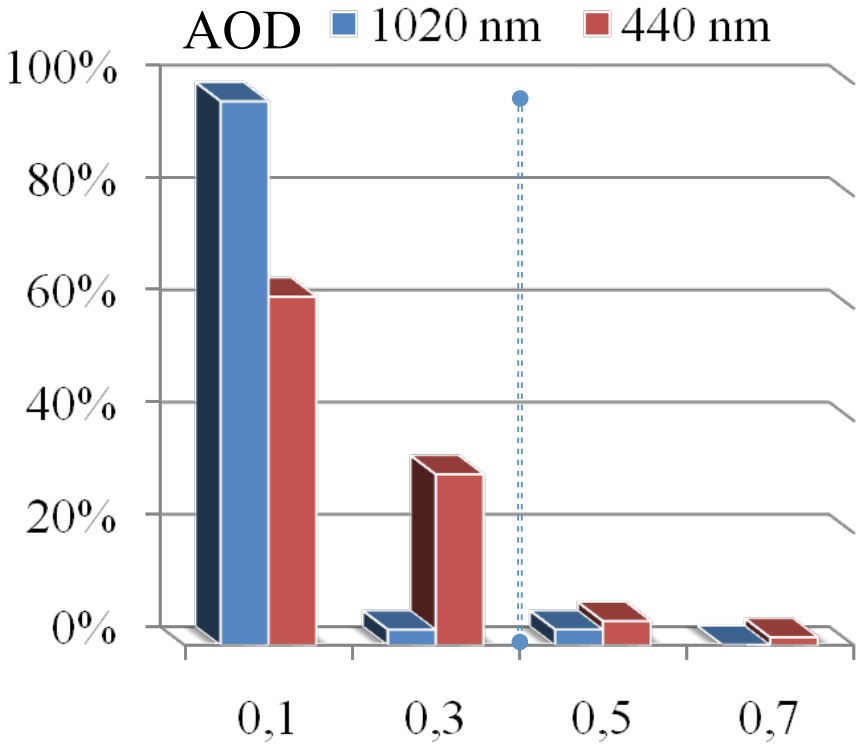
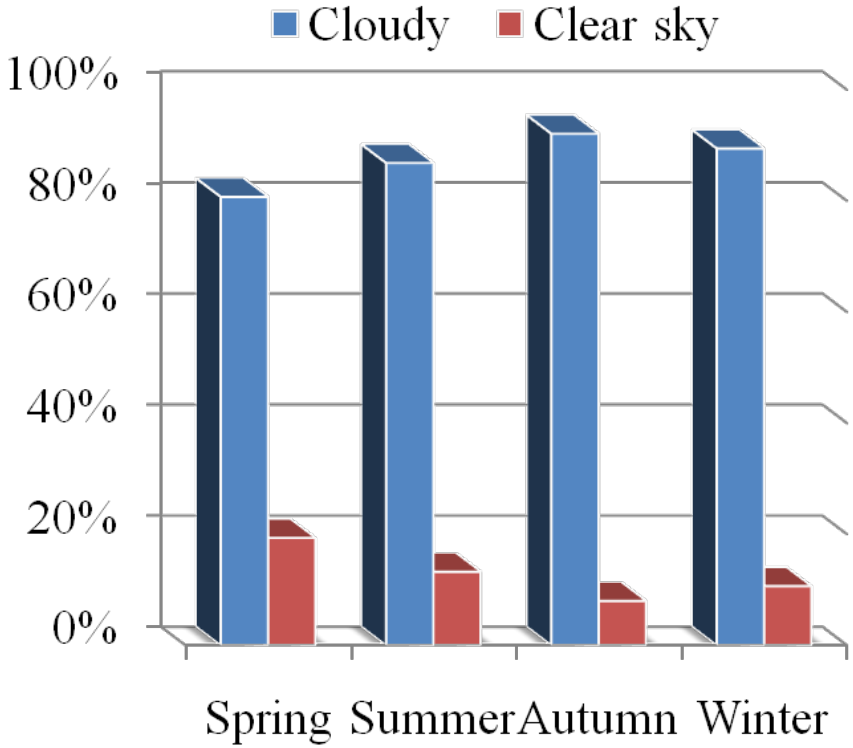






BACKGROUND cases ($AOD_{550nm} \approx 0.15$, Tomsk)

✓ Reliable aerosol optical / microphysical model for West Siberia **is absent**

THE BASIC AEROSOL MODELS USED IN RADIATIVE CALCULATIONS

WCP (World Climate Program)	• Water-soluble / Oceanic • Dust-like • Soot •75% H_2SO_4 • V-Ash	Optics (Continental)
OPAC (Optical Properties of Aerosols and Clouds)	• Water-soluble/Insoluble • Mineral • Soot • Sea-salt • Sulfate droplets	Optics (Continental average)
Medium-cycled model	• Vertical heterogeneous	Optics
Aircraft model In the processing	• 0 - 5 km	Optics & Microphysics

METHOD 1 (RTE-Inversion, Optics)

RADIATIVE TRANSFER EQUATION $\longrightarrow I_\lambda^{(c)}(\theta) = I\left(\theta_0, \tau_\lambda, \rho_\lambda, \omega_\lambda^{(i)}, g_\lambda^{(i)}(\theta)\right)$

Method of the RTE solution: statistical **Monte Carlo method**

- Vertical homogeneity
- Surface reflection – Lambert law
- Molecular absorption $I_\lambda^{(c)}(\theta) = C \cdot \exp\left(-\tau_\lambda - \tau_\lambda^{Gas}\right) \hat{I}_\lambda^{(c)}(\theta)$

$$X = X\left(\omega_\lambda^{(0)}, g_\lambda^{(0)}(\theta)\right) \dashrightarrow \left|I_\lambda^{(m)} - I_\lambda^{(c)}\right| < \delta_\lambda \dashrightarrow Y = Y\left(\omega_\lambda, g_\lambda(\theta)\right)$$

$$g_\lambda^{(j+1)}(\vartheta) = \gamma^{(j)}\left(I_\lambda^{(m)}, I_\lambda^{(c)}, I_\lambda^{(1,c)}\right) g_\lambda^{(j)}(\vartheta)$$

$$\omega_\lambda^{(j+1)} = \int_0^\pi g_\lambda^{(j+1)}(\vartheta)\, d\vartheta$$

METHOD 2 (Inversion, Microphysics & Optics)

$$X = \int_{r_{min}}^{r_{max}} K_{sca/ext}(\lambda, \theta, r, n, \kappa) \frac{dS}{dr} dr$$

- ❑ **Homogeneous spheres**
- ❑ **Spectral independent complex RI**
- ❑ **In the total atmospheric column**

$$X = \begin{bmatrix} D(\lambda_1, \theta_1) \\ \dots \\ D(\lambda_{K_D}, \theta_1) \\ \dots \\ D(\lambda_1, \theta_T) \\ \dots \\ D(\lambda_{K_D}, \theta_T) \\ \tau(\lambda_1) \\ \dots \\ \tau(\lambda_{K_\tau}) \\ \tau_s(\lambda_1) \\ \dots \\ \tau_s(\lambda_{K_\tau}) \end{bmatrix}$$

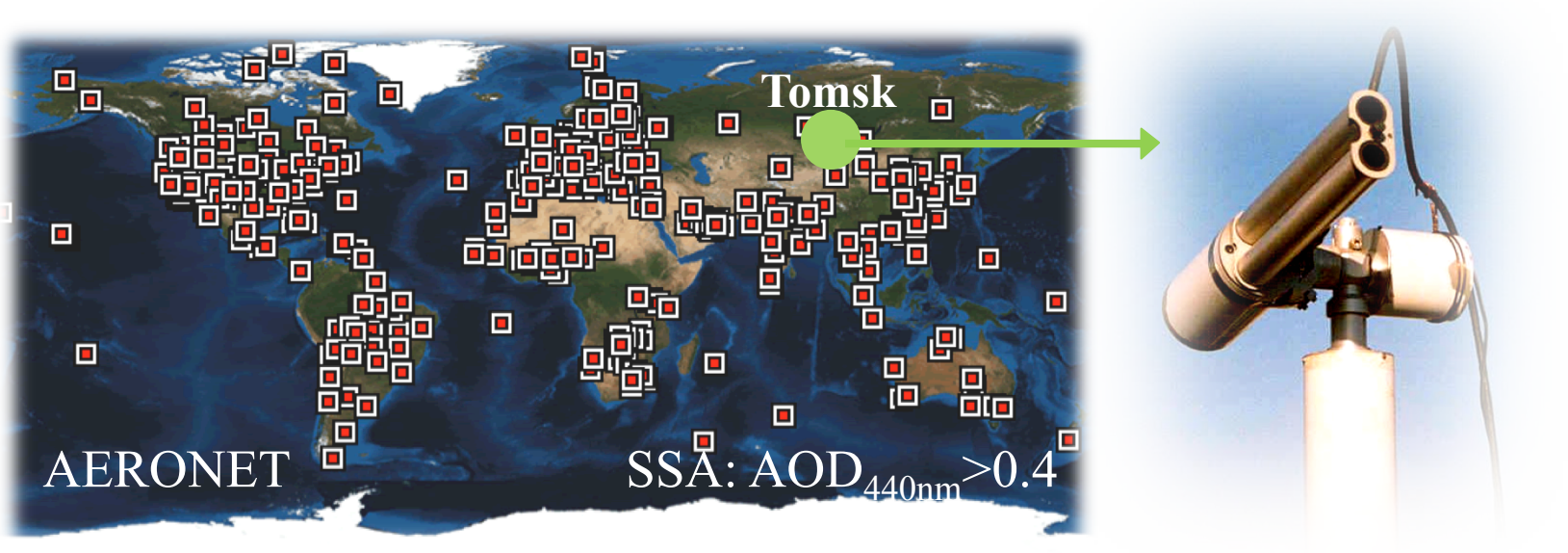
Volume scattering phase function / λ = 0.44, 0.675, 0.87, 1.02 μm /
Information source: **RTE-Inversion**

Aerosol optical depth / λ = **0.34, 0.38,** 0.44, 0.675, 0.87, 1.02 μm /
Information source: **AERONET**

Aerosol scattering optical depth / λ = 0.44, 0.675, 0.87, 1.02 μm /
Information source: **RTE-Inversion +AERONET**

EXPERIMENTAL BASE

7:20



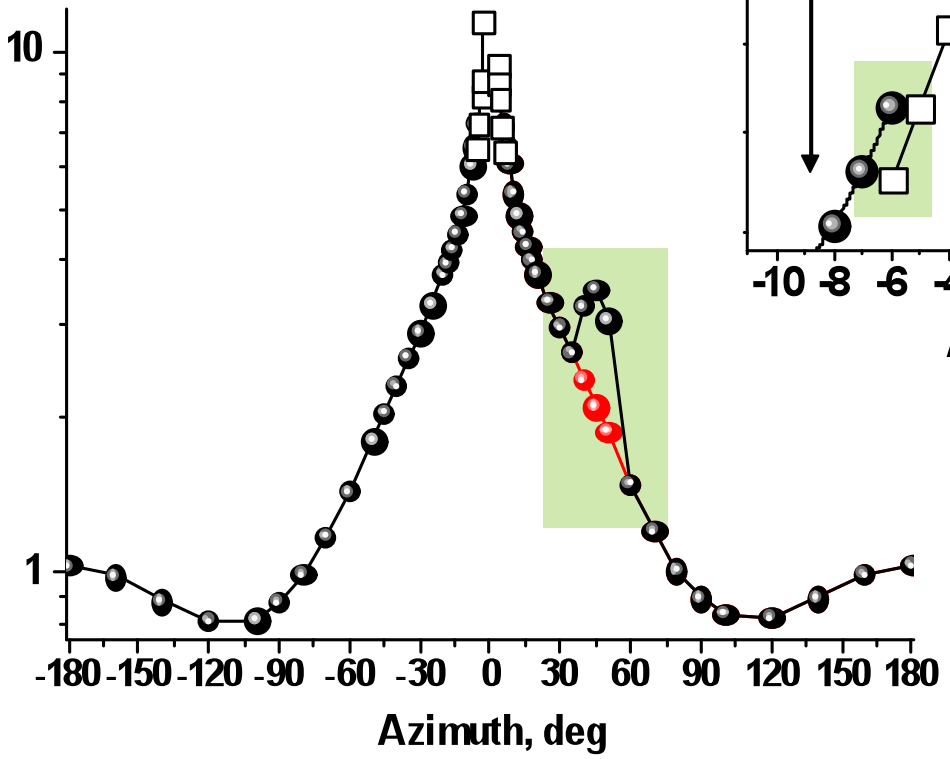
Sun/Sky photometer CIMEL CE-318, Tomsk station, Summer, 2003 – 2009

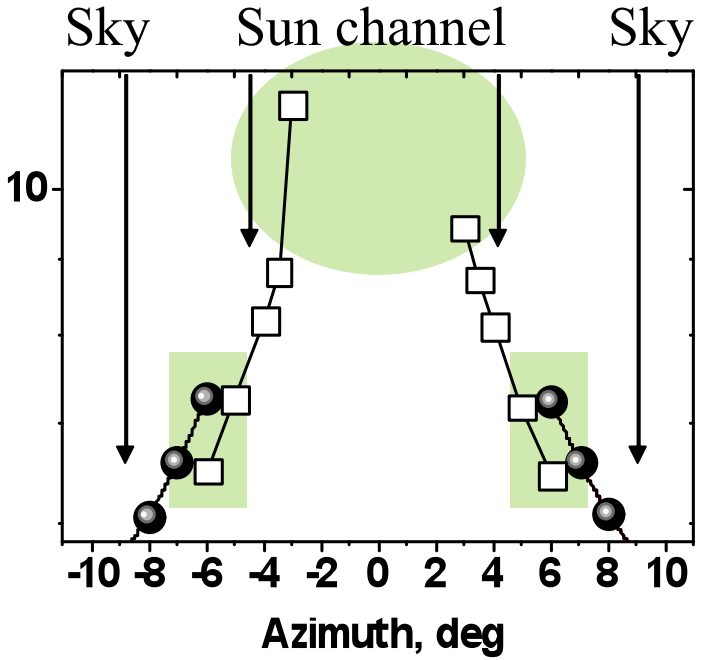
1. Solar almucantar Level 2.0 (440, 675, 870, 1020 nm)
2. Aerosol optical depth Level 2.0 (+ 340, 380 nm)

3. Molecular scattering / absorption optical depth
4. Surface albedo

SELECTION STRATEGY

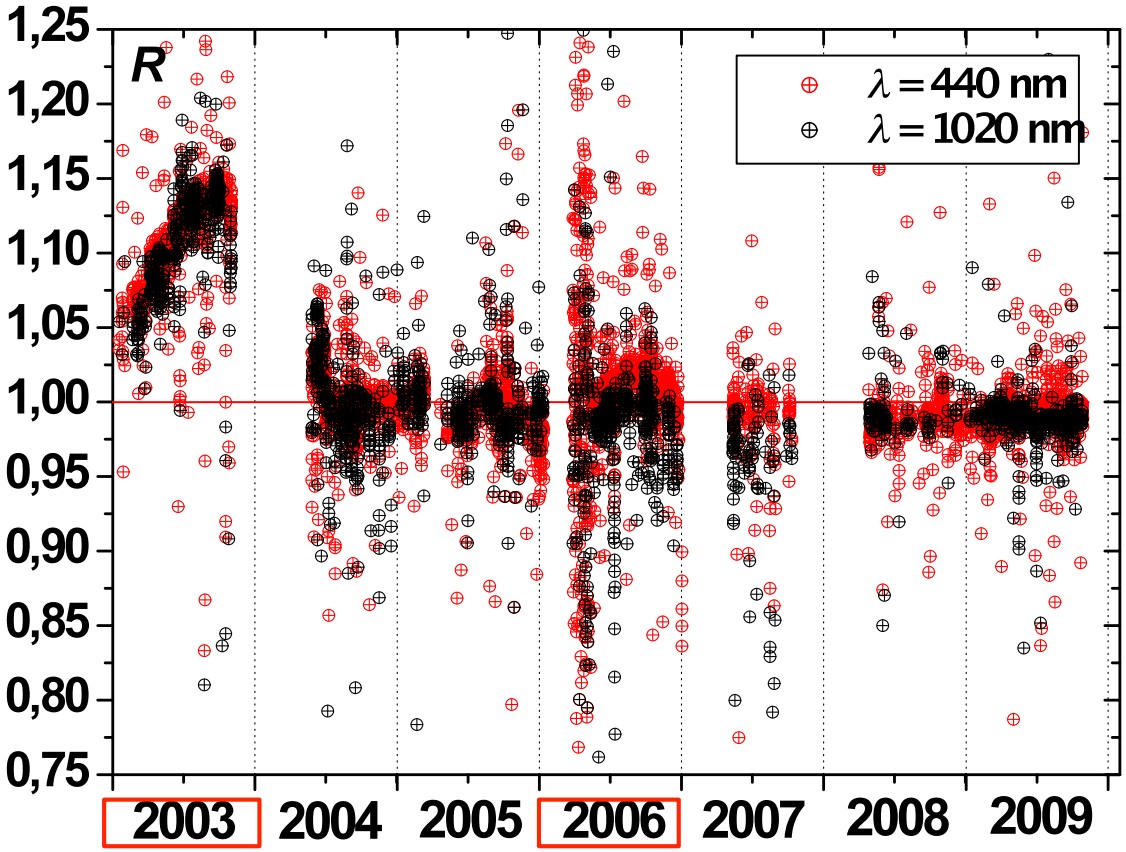
- Aureole radiance at 3 deg. /azimuth/ is excluded
- Aureole symmetry ($\delta \leq 10\%$)
- Almucantar symmetry ($\delta \leq 10\%$)
- Sun and Sky channels accordance ($\geq 95\%$)





SELECTION STRATEGY

$$R_\lambda = I_\lambda^{Sun}(\varphi = 6°) / I_\lambda^{Sky}(\varphi = 6°)$$



Zenith angle $\theta_0 > 50°$

Background cases:

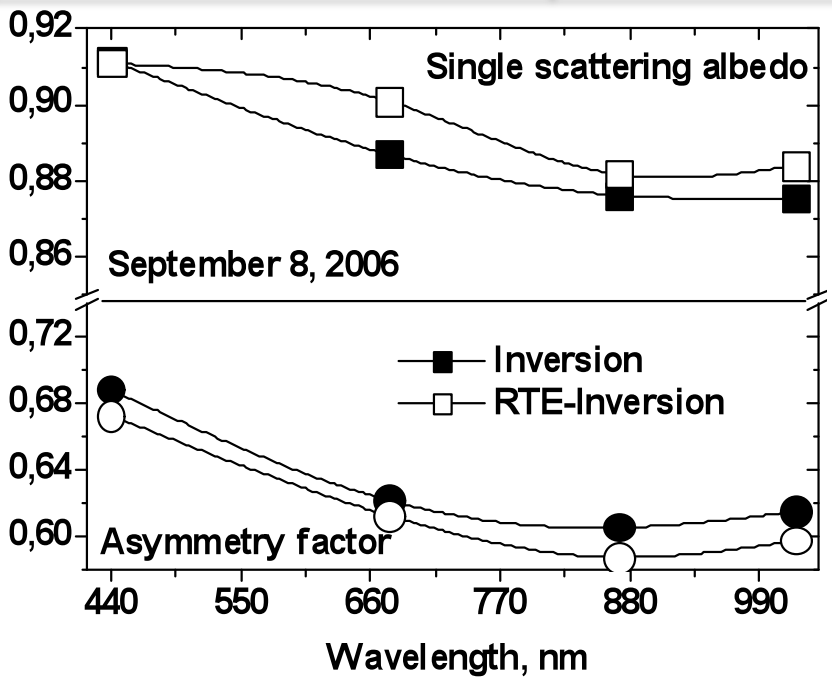
- $AOD_{440nm} < 0.4$
- $AOD_{1020nm} > 0.05$

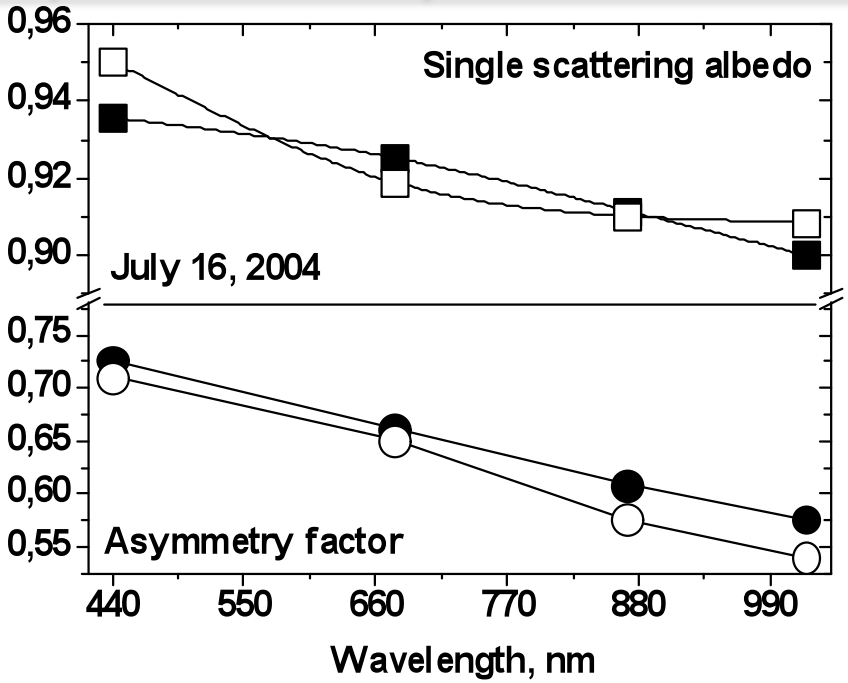
BACKGROUND cases ($AOD_{550nm} \approx 0.15$, Tomsk)

10:20

OPTICAL CHARACTERISTICS

Date	AOD_{440nm}	AOD_{1020nm}	Zenith angle, deg
September 8, 2006, 01:28 GMT	0.23	0.08	75
July 16, 2004, 00:40 GMT	0.32	0.09	70





*Notes
- Inversion: Inversion of Fredholm equation
- RTE-Inversion: Retrieval by RTE solution

BACKGROUND cases ($AOD_{550nm} \approx 0.15$, Tomsk)

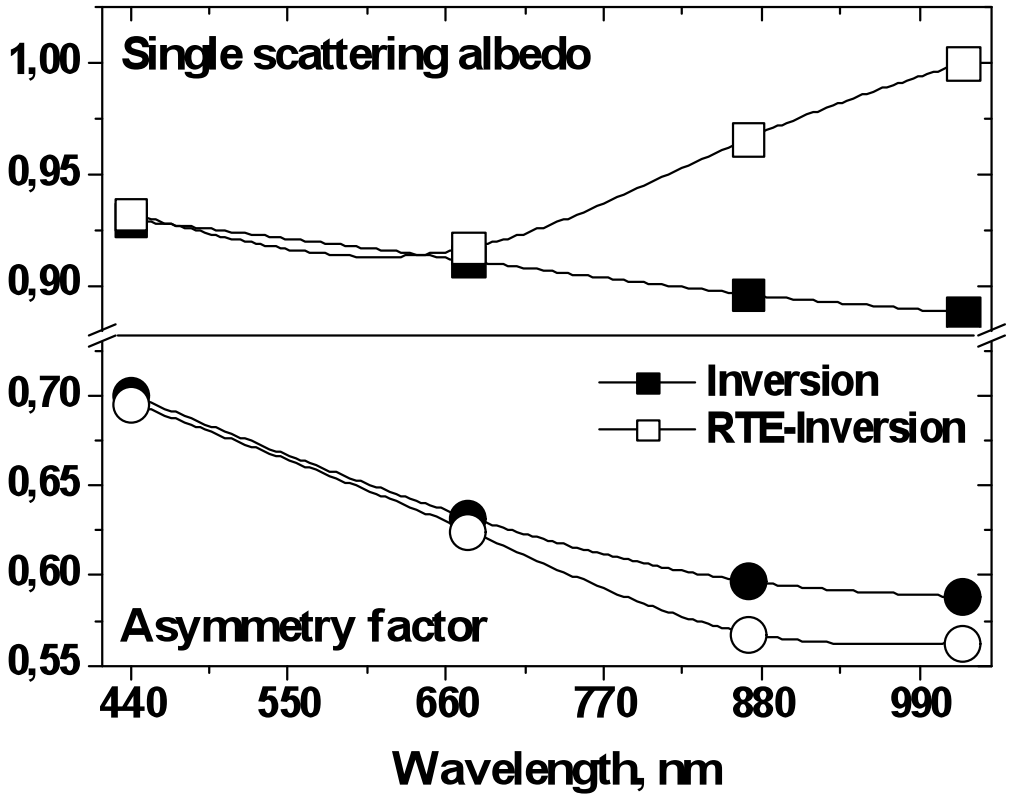
11:20

Measurement data

Date	AOD_{440nm}	AOD_{1020nm}	Zenith angle, deg
August 18, 2005, 11:25 GMT	0.28	0.07	71

Potential reasons of deviation from monotony /RTE – Inversion/:

- AOD errors
- Thin cirrus clouds

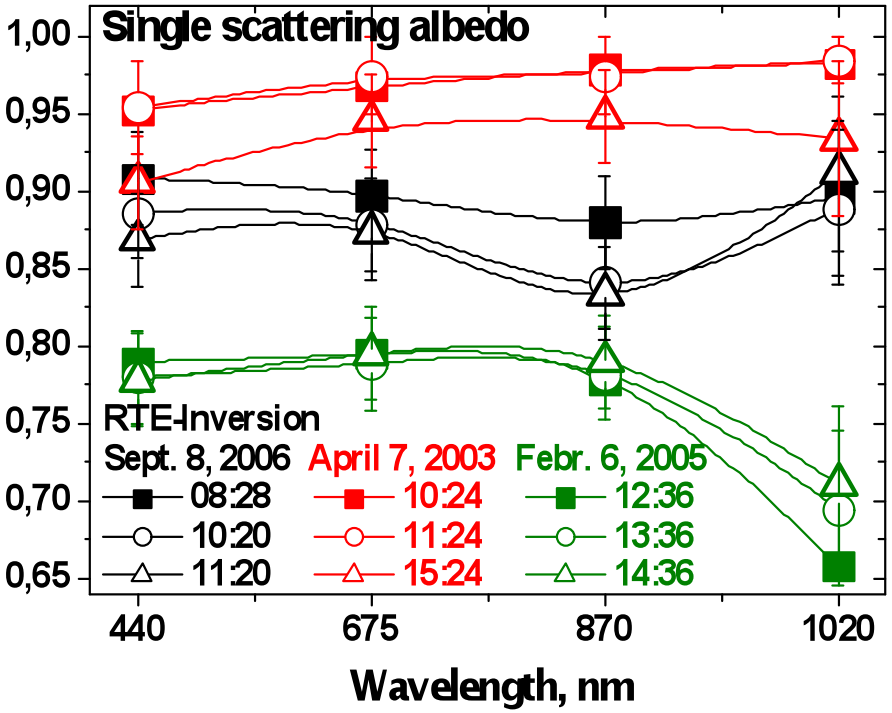


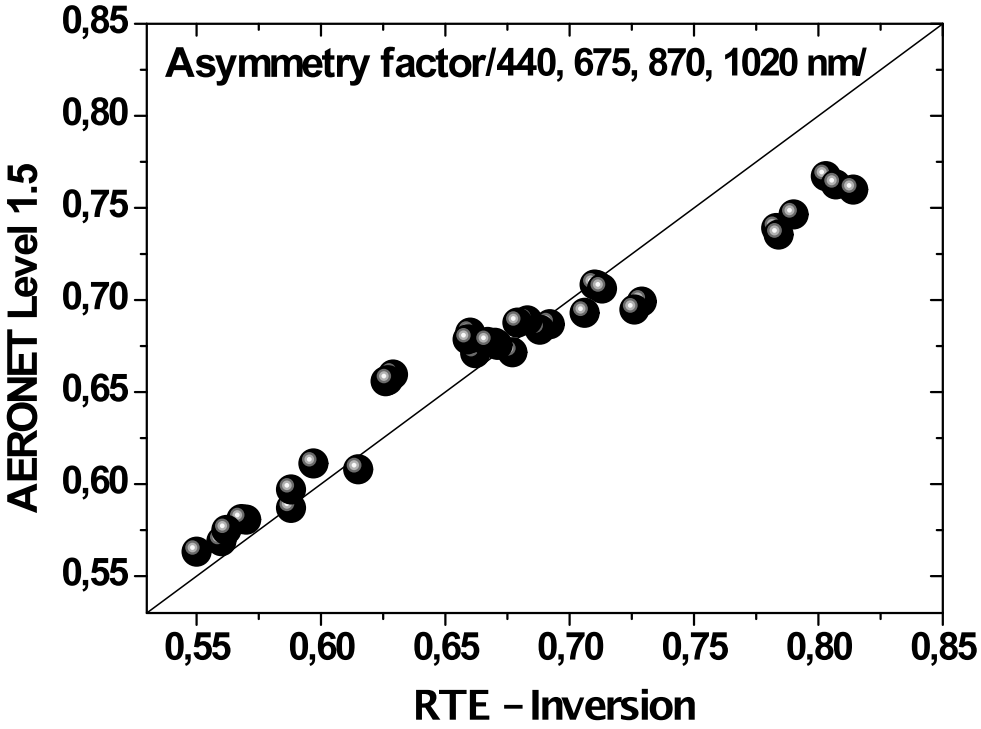
BACKGROUND cases ($AOD_{550nm} \approx 0.15$, Tomsk)

12:20

Measurement data /different seasons/

Date	AOD_{440nm}	AOD_{1020nm}	Zenith angle, deg
September 8, 2006	~ 0.22	~ 0.07	55 – 75
April 7, 2003	~ 0.24	~ 0.10	55 – 60
February 6, 2005	~ 0.20	~ 0.10	70 – 75



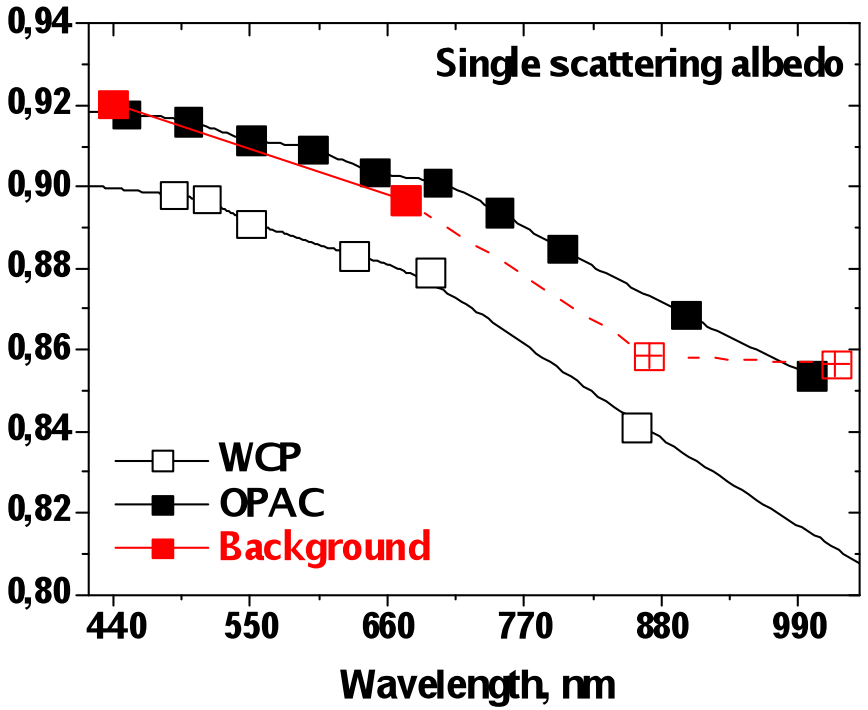


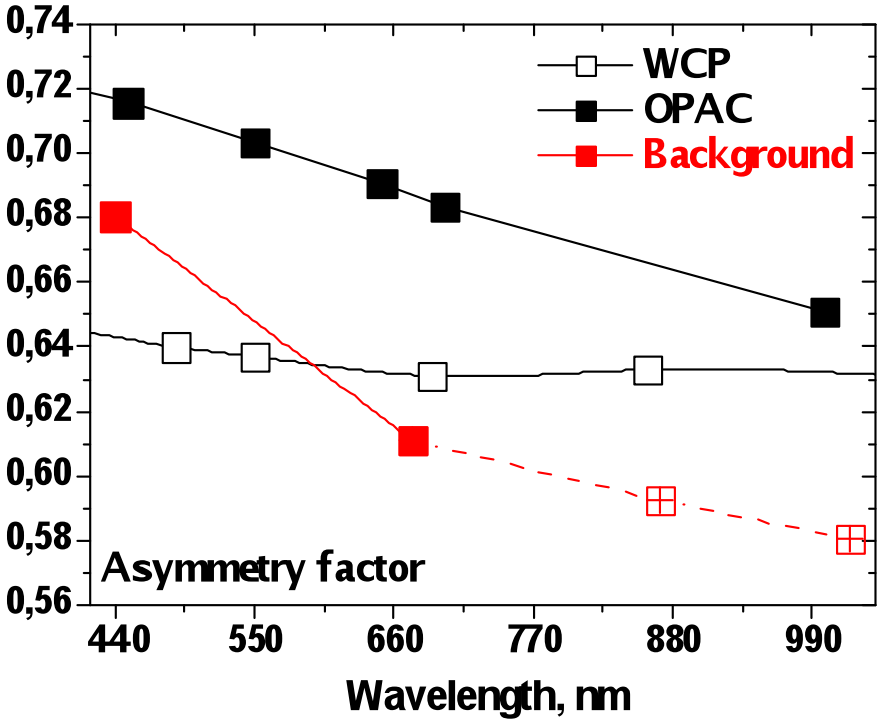
BACKGROUND cases vs. MODELS

13:20

Averaging strategy

- All ascending steady SSA spectral trends
- All descending steady SSA spectral trends
- SSA values at 870 and 1020 nm are excluded in some cases



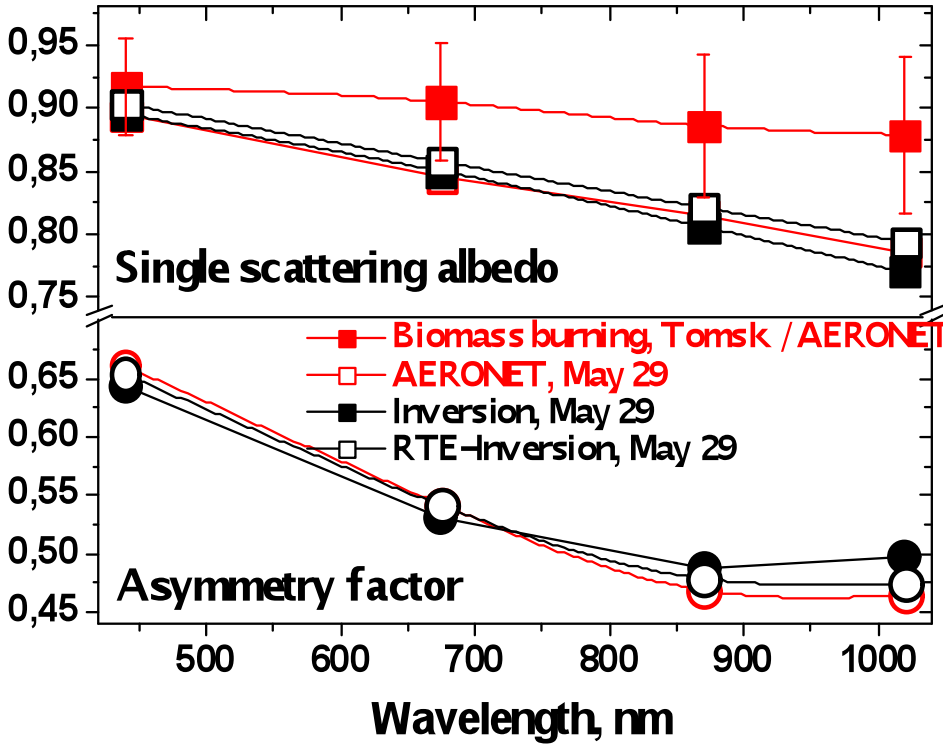


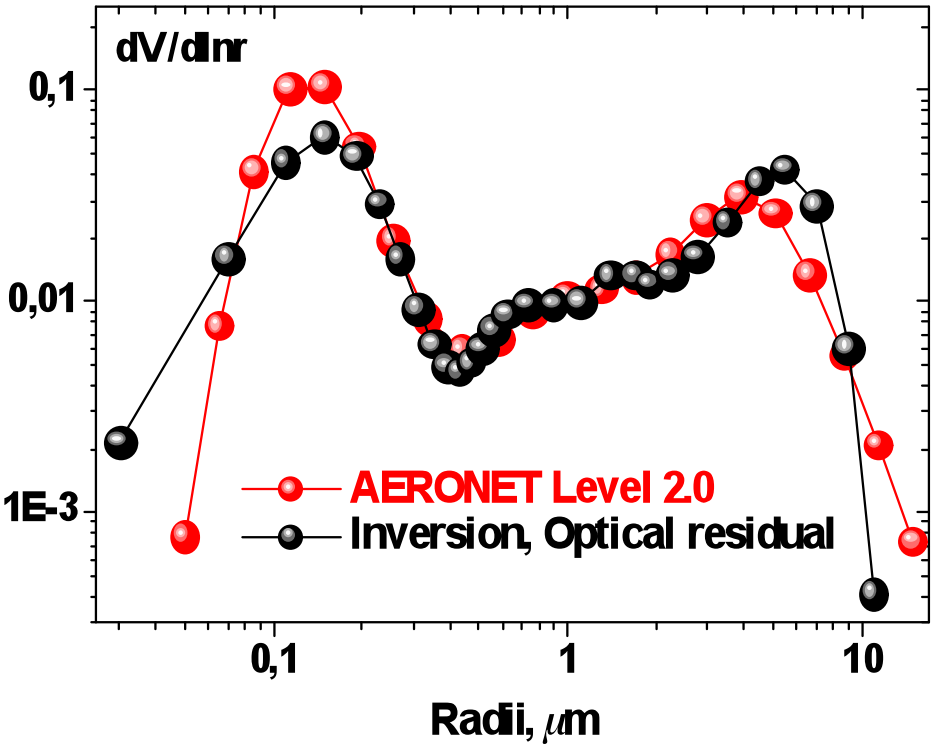
BIOMASS BURNING cases ($AOD_{440nm} > 0.4$)

14:20

Measurement data

Date	AOD_{440nm}	AOD_{1020nm}	Zenith angle, deg
May 29, 2004, 00:30 GMT	0.65	0.15	70



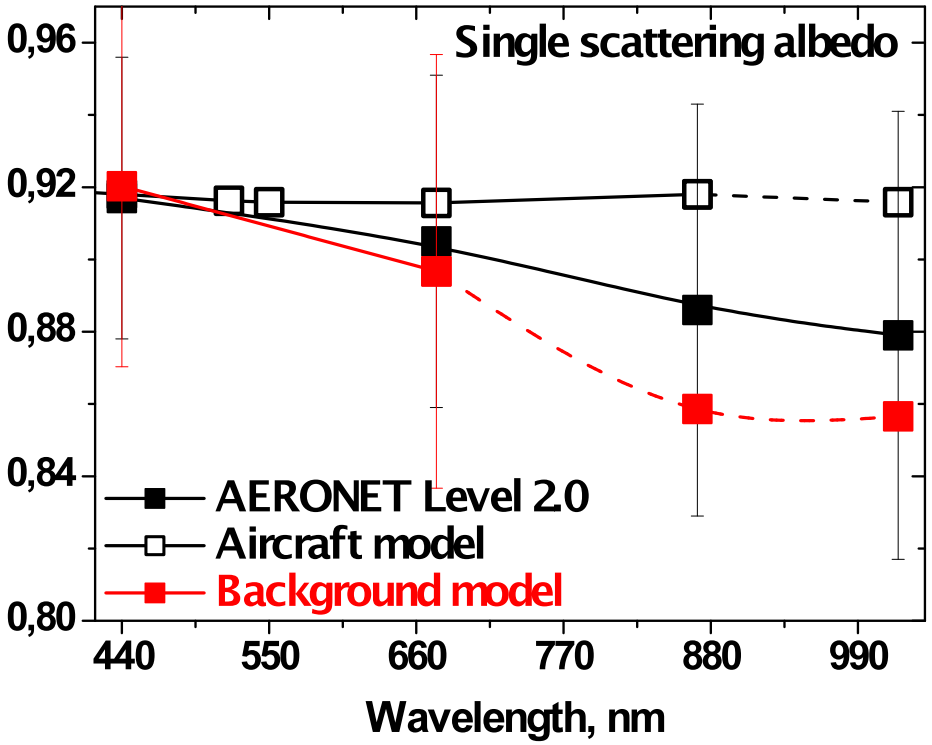


Aerosol absorption: HIGH vs. LOW turbidity

15:20

TOMSK

1. **AERONET Level 2.0, high AOD, 2002 – 2008**
2. **Aircraft sensing data, low AOD, 1986 – 1988, 1997 – 2009**
   - **Aethalometer, in situ measurements, 0 – 5 km**
3. **Background model, low AOD, 2002 - 2009**



BLACK CARBON content and specific absorption

16:20

Morphology

- Internal mixture: H_2O, $(NH_4)_2SO_4$ and BC
- Maxwell Garnett effective medium approximation

Retrieval technique / Schuster G.L. et. al. 2005 /

- **Column-averaged concentration**

$$[BC] = \rho_{BC} \cdot f_{BC} \cdot \int \frac{dV}{d\ln r} d\ln r, \quad f_{BC} = F\left((n - m \cdot i)_{MG}, (n - m \cdot i)_{AERONET}\right)$$

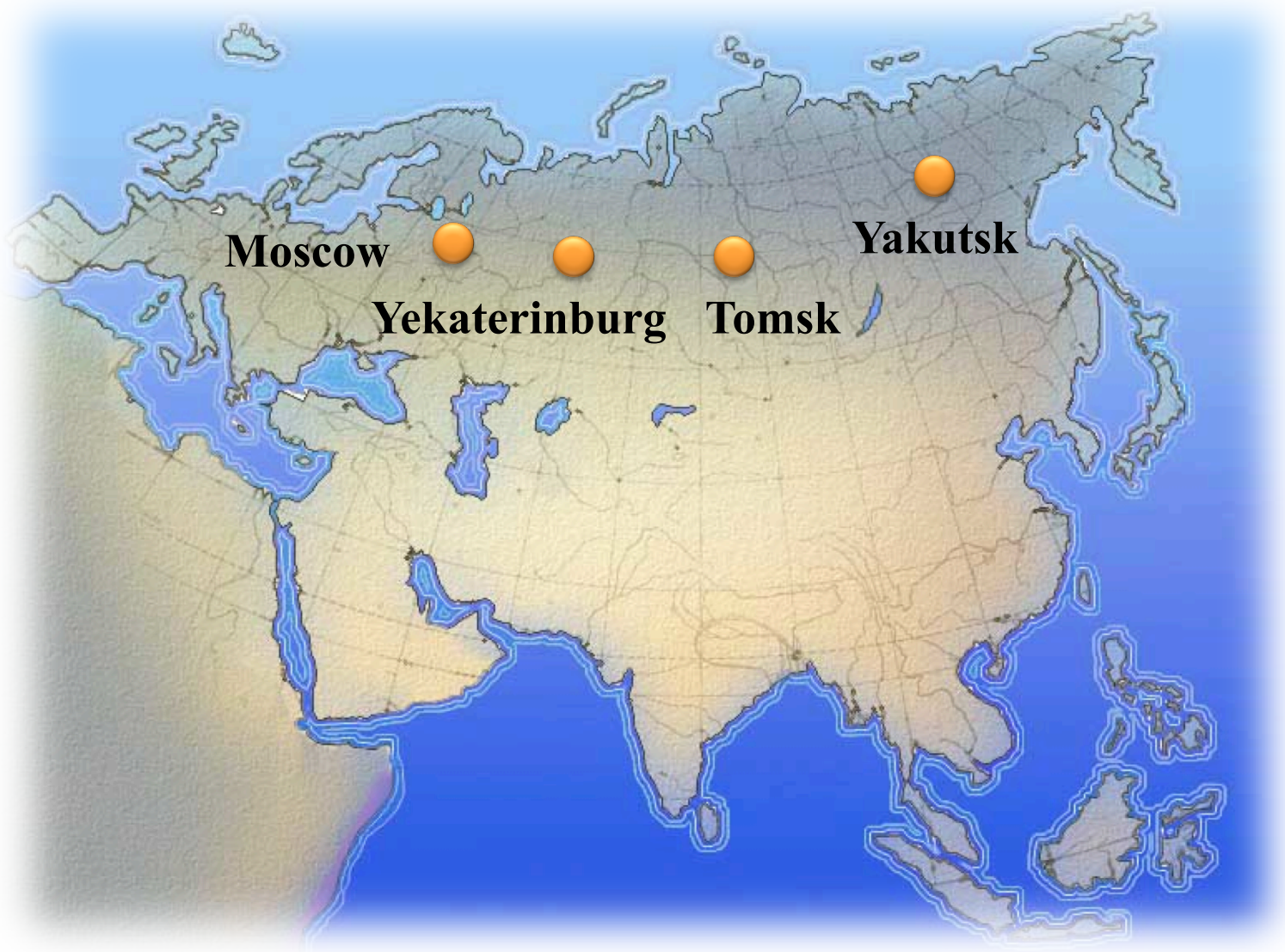
- **Specific absorption**

$$\alpha_{BC}^{\lambda} = \frac{\left(1 - \omega_a^{\lambda}\right) \tau_a^{\lambda}}{[BC]}$$

Parameter	H_2O	$(NH_4)_2SO_4$	BC
Refractive index	**$1.33 - 1.96 \cdot 10^{-9}i$**	**$1.53 - 10^{-7}i$**	**$1.8 - 0.74i$**
Density, g/cm^3	**-**	**-**	**1.85**

SITES

17:20



BLACK CARBON content and specific absorption

18:20

Site	Latitude, deg	BC fraction, %	Specific absorption, m^2/g, λ = 550 nm		[BC], mg/m^2		Number of retrievals
Moscow	55N	1.8	9.4	SD = 2.0	4.4	SD= 2.4	287 / 2001 – 2009
Yekaterinburg	57N	1.1	10.3	SD = 1.4	3.0	SD= 2.0	80 / 2006 – 2010
Tomsk	56N	1.7	9.2	SD = 1.5	5.2	SD= 3.8	113 / 2003 – 2010
Yakutsk	61N	1.2	11.3	SD = 2.5	2.3	SD= 1.6	54 / 2004 - 2009

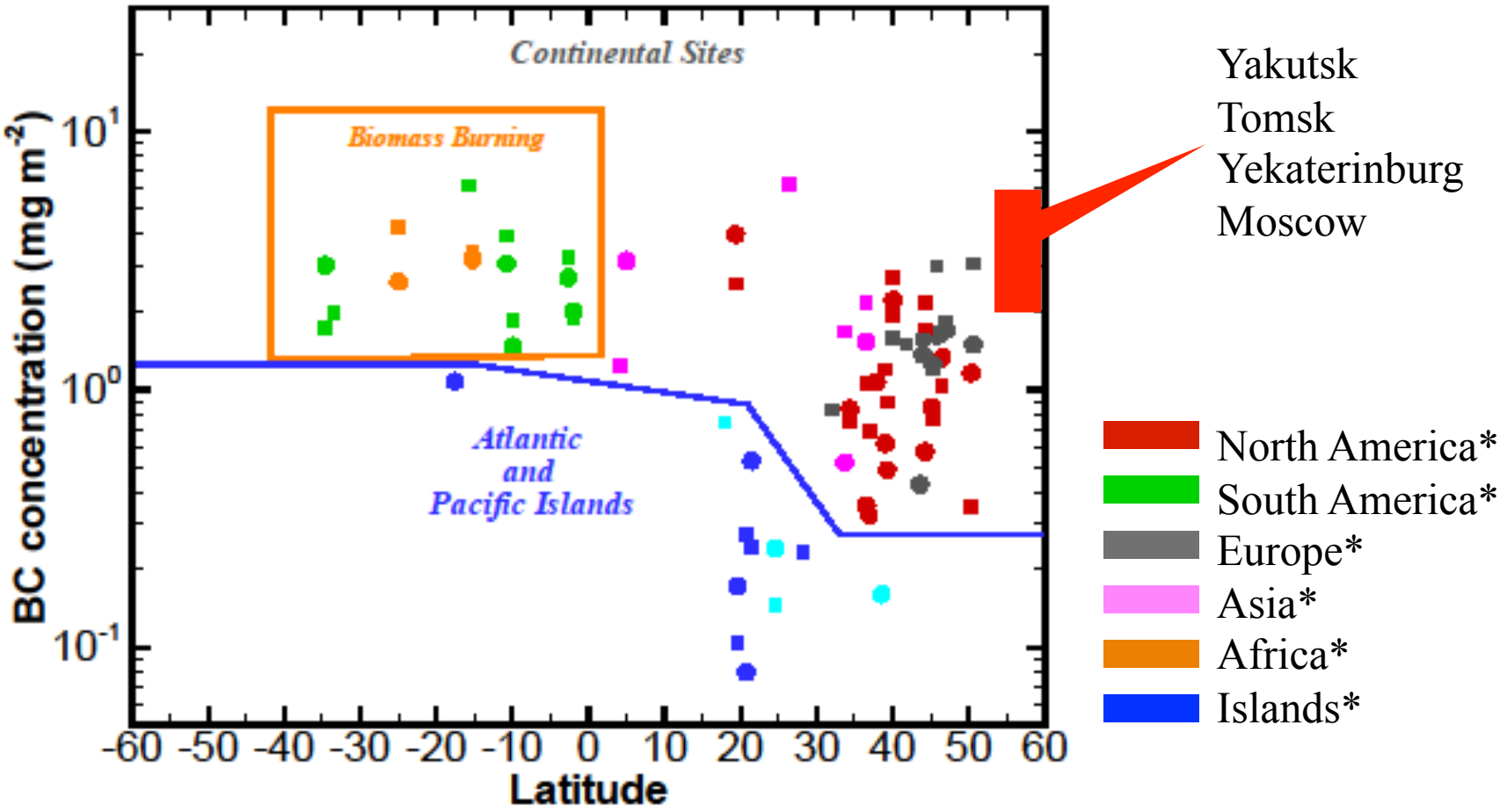
SD – standard deviation

* – Schuster G.L. et al. Black carbon and specific absorption from the Aerosol Robotic Network, 2005

Site	Latitude, deg	Specific absorption, m^2/g, λ = 550 nm		[BC], mg/m^2	Number of retrievals
Krasnoyarsk*	56N	9.3	SD = 1.7	-	78 / 2000
Mauna Loa*	20N	9.9	SD = 1.2	-	662 / 2000 – 2001
Mexico City*	19N	9.6	SD = 1.0	-	263 / 2000 – 2001
Bratts Lake*	50N	10.3	SD = 1.2	-	243 / 2000 – 2001

BLACK CARBON content vs. Latitude

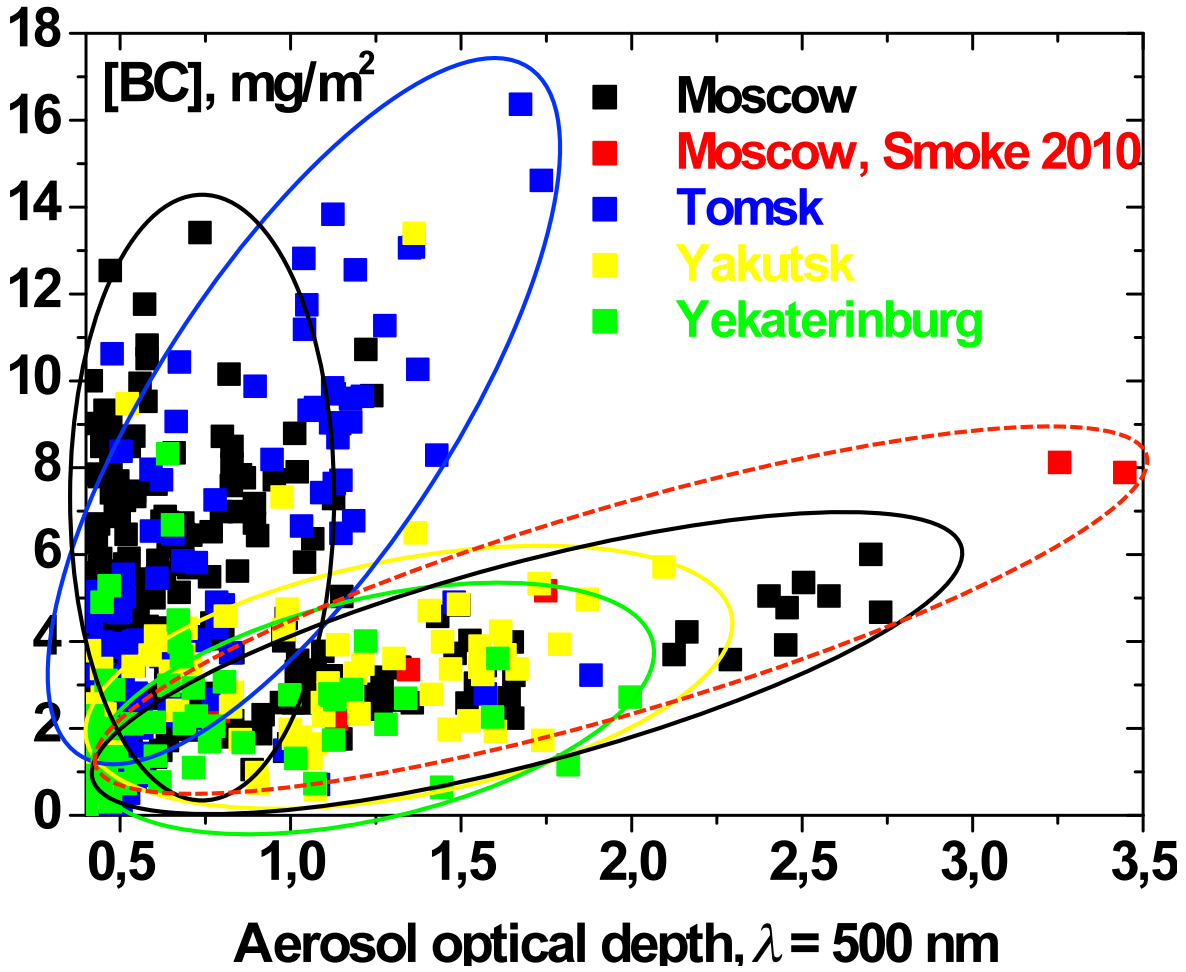
19:20



*Schuster G.L. et al. Black carbon and specific absorption from the Aerosol Robotic Network, 2005

BLACK CARBON content vs. AOD

20:20



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THANKS
FOR YOUR ATTENTION!

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