JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D10220, doi:10.1029/2006JD007947, 2007

Aerosol optical and microphysical properties over the Atlantic Ocean during the 19th cruise of the Research Vessel *Akademik Sergey Vavilov*

S. M. Sakerin,[1] A. Smirnov,[2,3] D. M. Kabanov,[1] V. V. Pol'kin,[1] M. V. Panchenko,[1] B. N. Holben,[3] and O. V. Kopelevich[4]

Received 22 August 2006; revised 15 February 2007; accepted 28 February 2007; published 26 May 2007.

[1] This paper presents aerosol optical depths in the total atmospheric column, aerosol size distributions, number concentrations and black carbon mass concentrations at the deck level measured in October–December 2004 on board the R/V *Akademik Sergey Vavilov*. Aerosol optical depths measured within the spectral range 0.34–4.0 μm were close to background oceanic conditions ($\sim$0.04–0.08) in the high-latitude southern Atlantic. Angstrom parameters derived within 440–870 nm and 870–2150 nm spectral ranges did not exceed 0.6, yielding averages of 0.34 and 0.12, respectively. The mass concentration of black carbon varied within the range 0.02–0.08 $\mu g/m^3$ in the 34–55°S latitudinal belt. The average of 0.04 $\mu g/m^3$ (s.d. $\sim$0.015) is close to the reported results for the remote areas of the South Indian Ocean. Aerosol volume size distributions measured within the size range of 0.4–10 μm can be characterized by a geometric volume mean radius $\sim$3 μm. This is consistent with the columnar retrievals reported by the Aerosol Robotic Network (AERONET).

Citation: Sakerin, S. M., A. Smirnov, D. M. Kabanov, V. V. Pol'kin, M. V. Panchenko, B. N. Holben, and O. V. Kopelevich (2007), Aerosol optical and microphysical properties over the Atlantic Ocean during the 19th cruise of the Research Vessel *Akademik Sergey Vavilov*, *J. Geophys. Res.*, *112*, D10220, doi:10.1029/2006JD007947.

1. Introduction

[2] The accuracy of the direct aerosol forcing computations depends mainly on the quality of aerosol models. The quality of aerosol models, in turn, strongly depends on the amount of empirical data and extensive coverage area. Collecting data over the oceans has never been an easy task. Being time, and labor consuming and also very expensive, those measurements made from research vessels were rare and definitely did not cover all regions of the World Ocean. Measurements in coastal zones and from island sites made within the framework of the internationally federated AERONET program [*Holben et al.*, 1998] or made by individual institutions do not fully solve the problem of disparate data coverage. There are still many areas over the oceans where information on atmospheric optical properties is completely or partly missing. In some areas ship-based measurements is the only data collection option.

[3] Various reviews published to date on aerosol optical depth measurements over the oceans [*Barteneva et al.*, 1991; *Smirnov et al.*, 2002; *Sakerin and Kabanov*, 2002; *Quinn and Bates*, 2005] illustrate that Sun photometer data were taken more frequently over the northern and central Atlantic, including inland seas and coastal areas, the Central Pacific, and to some extent over the northern Indian Ocean. The atmosphere of the southern Atlantic, especially south of 40° ("roaring forties") lacks not only reliable data but in point of fact any data on aerosol optical depth and can be considered as one of the most poorly studied parts of the World Ocean.

[4] Because of its absorption properties and long residence time in the atmosphere black carbon is an important anthropogenic aerosol component [*Penner and Novakov*, 1996]. According to *Jacobson* [2001], black carbon's contribution to the direct radiative forcing exceeds that due to CH_4. The important role of black carbon in the atmospheric radiation balance has created a demand for more data acquisition and analysis [see, e.g., *Novakov et al.*, 1997, 2003, 2005; *Hansen et al.*, 2000]. Black carbon measurements are sparse over the oceans, especially in remote oceanic areas.

[5] Despite aerosol size distribution measurement results can be subject to various specific instrumental biases (see, e.g., comprehensive analysis by *Reid et al.* [2003, 2006]), we believe that new experimental data can still be a very useful addition, especially to such poorly studied areas as the southern Atlantic.

[6] In the current paper we report aerosol optical depth measurements over the Atlantic Ocean, aerosol size distribution and number concentration measurements at deck

[1]Institute of Atmospheric Optics, Russian Academy of Sciences, Siberian Branch, Tomsk, Russia.
[2]Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County, Baltimore, Maryland, USA.
[3]Biospheric Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.
[4]P. P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia.

0148-0227/07/2006JD007947$09.00

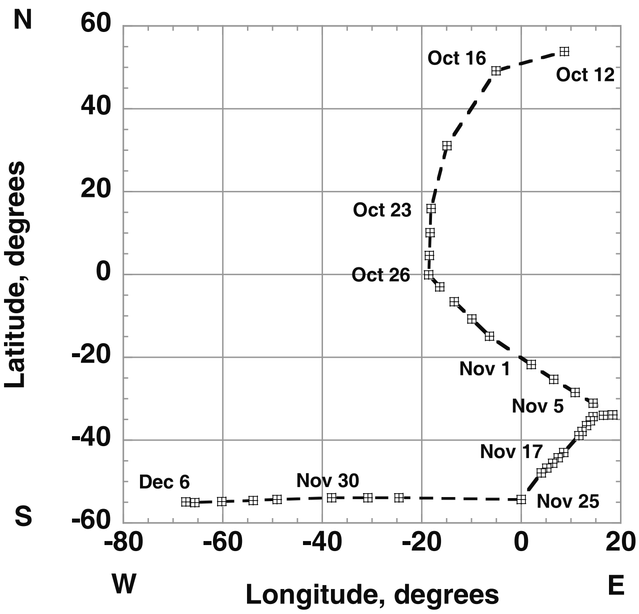

Figure 1. R/V *Akademik Sergey Vavilov* cruise track.

level, acquired within the 0.4–10 μm size range, and black carbon concentration data.

2. Instrumentation and Data Collection

[7] Aerosol measurements were made from October to December 2004 on board the R/V *Akademik Sergey Vavilov*. The cruise area included a transect in the Atlantic from the North Sea to Cape Town, South Africa and then a crossing in the South Atlantic to Ushuaia, Terra del Fuego, Argentina (Figure 1). Aerosol measurements included (1) columnar aerosol optical depth using the automated Sun photometer SP-5 [*Sakerin and Kabanov*, 2002] and a hand-held Sun photometer Microtops II [*Morys et al.*, 2001]; (2) deck-level aerosol size distribution measurements acquired within the 0.4–10 μm diameter range using the electric particle counter AZ-5 [*Sokolov and Sergeyev*, 1970]; and (3) black carbon mass concentration measurements using an in-house soot measuring device (aethalometer) [*Kozlov et al.*, 1997].

[8] Instruments were collocated on the upper deck of the ship in order to avoid Sun photometer line-of-sight obstructions and to minimize the influence of local aerosol sources.

[9] The SP-5 multiwavelength Sun photometer is an automated device specifically designed to measure columnar optical depth and water vapor content as described in detail by *Sakerin and Kabanov* [2002] and *Sakerin et al.* [2005]. In the UV spectral range the SP-5 has a SiC detector for two spectral channels, a silicon photodiode is used for 10 visible and near-IR channels, and a pyroelectric detector is deployed for the short-wave IR channels. Basic spectral characteristics of the interference filters are summarized in Table 1. The photometer is mounted on a two coordinate (zenith/azimuth) turntable. Electric drives are controlled by a system of photosensors, including four photodiodes for coarse pointing and a four-sector photodiode for precise tracking.

[10] The measurements were carried out in weather conditions when the solar disk was free of clouds and solar zenith angle was less than 80°. The instrument was precalibrated using the Langley method but after some precruise repairs the calibration was repeated while at sea on clear days during the morning hours. The calibration scheme and the procedure for computing optical depth and columnar water vapor content (in cm of precipitable water) are given by *Sakerin and Kabanov* [2002] and *Kabanov and Sakerin* [1997]. The principal idea of the computational algorithm is to take into account molecular scattering and gas absorption at the initial stage, dividing the measured signal by the transmission functions computed using the LOWTRAN-7 spectroscopy [*Kneizys et al.*, 1988] and Sun photometer spectral functions. The uncertainty of aerosol optical depth in the UV channels does not exceed 0.02, being between 0.01 and 0.02 for visible and near IR range, and increasing to 0.02–0.03 for the SWIR channels.

[11] We averaged a 30-min measurement period into one data point. Daily averages were calculated as a simple arithmetic mean of the 30-min averages. We characterized the temporal and latitudinal distribution of aerosol optical depth using the daily averaged values and Angstrom parameter α computed as a square-linear fit to the classical equation $\tau_a \sim \lambda^{-\alpha}$. The Angstrom parameter α was derived for two spectral ranges: 440–870 nm and 870–1250 nm.

4. Conclusions

[31] A summary of the optical parameters, microphysical parameters, and soot concentrations for the less frequently studied Southern Atlantic region is presented in Table 2.

[32] Table 2 shows that atmospheric aerosol optical parameters (τ_a(500 nm) ~0.05 and $\alpha_{vis} \sim 0.34$) in the southern Atlantic between 34°S and 55°S are similar to typical values measured in other remote oceanic areas. However, the employment of a wider spectral range in the current study ensures that this data is particularly unique and valuable. In the SWIR spectral range the wavelength dependence of aerosol optical depth remains almost neutral ($\alpha_{nir} \sim 0.12$).

[33] The BC mass concentrations in the Southern Hemisphere were low (~0.04 $\mu g/m^3$) and relatively stable.

[34] The volume geometric mean radius $R_v \sim 3\mu m$ and the geometric standard deviation $\sigma \sim 0.6$ of the volume size distribution derived from in situ aerosol measurements are consistent with the parameters derived from AERONET data [*Smirnov et al.*, 2003a].

Table 1. Filter Characteristics of SP-5 Sun Photometer

	UV Range	VIS and NIR Range	SWIR Range
Field of view, deg	0.92	1.50	1.15
Number of channels	2	10	4
Filter wavelengths, nm	340, 370	420, 440, 480, 550, 630, 680, 780, 870, 940, 1060	1240, 1560, 2150, 4000
FWHM, nm	5	5–15	10–50
Time of one cycle, s	50	50	50