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Ship-based aerosol optical depth measurements in the Atlantic Ocean: Comparison with satellite retrievals and GOCART model

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[1] Aerosol optical depth measurements were made in October–December 2004 onboard the R/V Akademik Sergey Vavilov. The cruise area included an Atlantic transect from North Sea to Cape Town and then a crossing in the South Atlantic to Argentina. In the open oceanic areas not influenced by continental sources aerosol optical depth values were close to background oceanic conditions ($\tau_a \sim 0.06-0.08$). Spectral dependence, especially in the high latitude Southern Atlantic, can be considered as quasi-neutral (Angstrom parameter α was less than 0.4). Back-trajectory analysis allowed statistical division of the aerosol optical parameters and showed similar properties for the North Atlantic polar marine, South Atlantic subtropical marine and South Atlantic polar marine air. Ship-borne aerosol optical depth comparisons to GOCART model and satellite retrievals revealed systematic biases. Satellite retrieved optical depths are generally higher by 0.02–0.07 (depending on the sensor), especially in low τ_a conditions. GOCART model simulated optical depths correlate well with the ship measurements and, despite overall bias and a notable disparity with the observations in a number of cases, about 30% agree within ±0.01. **Citation:** Smirnov, A., et al. (2006), Ship-based aerosol optical depth measurements in the Atlantic Ocean: Comparison with satellite retrievals and GOCART model, *Geophys. Res. Lett.*, *33*, L14817, doi:10.1029/2006GL026051.

1. Introduction

[2] Atmospheric optical properties over the oceans were not well studied until the mid-sixties of the last century. Remarkable progress has been made since then in our understanding of aerosol generation, evolution, transport, the way aerosol particles act as cloud condensation nuclei, affect microphysics of clouds and their ability to precipitate. Substantial radiative effects of sea-salt aerosol, better understanding of the climate change forcing by aerosols [*Haywood et al.* 1999; *Kaufman et al.*, 2005], combined with very few systematic measurements over the oceans [*Smirnov et al.*, 2002], especially in the South Ocean, create a demand for more data acquisition. Recently the Aerosol Robotic Network (AERONET) [*Holben et al.*, 1998] established a few new island sites in the Southern Ocean, however, large areas south of 35° still have no coverage. Ship-based measurements can at least partly fill the gap which exists in our knowledge on the global aerosol distribution over the oceans.

[3] Ship-based measurements of columnar aerosol optical properties are extremely valuable for several important reasons. First, not all areas of the World Ocean can be studied from islands therefore ship-based measurements are the only source of data for such regions (e.g., areas south from the "roaring forties" in the South Atlantic). Second, it is not absolutely clear to what extent an island, acting as a local perturbator and/or source of aerosol, can alter aerosol optical depth and its spectral dependence. Finally, ship-based data can be advantageously used for validation of global aerosol transport model simulations and satellite retrievals (data on aerosol optical depth over the oceans were successfully employed in the regional [*Ignatov et al.*, 1995] and in the global validation of two channel AVHRR aerosol optical thickness retrievals [*Liu et al.*, 2004]). Certain steps in these directions have been recently made and hopefully will continue [*Sakerin and Kabanov*, 2002; *Knobelspiesse et al.*, 2004].

[4] In the current paper we present some new results on aerosol optical depth measurements in the Atlantic (mainly in the Southern Atlantic) Ocean and compare ship-borne measurements to satellite retrievals from various sensors and to the global transport model GOCART.

2. Instrumentation and Data Collection

[5] Aerosol optical depth measurements were made in October–December 2004 onboard the R/V Akademik Sergey Vavilov. The cruise track 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). The cruise track allowed sampling of several aerosol regimes over the Northern and Southern Atlantic. A hand-held sunphotometer (Microtops II) was used to acquire 314 series of measurements spanning 38 days.

[6] The Microtops II sun photometer is a handheld instrument specifically designed to measure columnar

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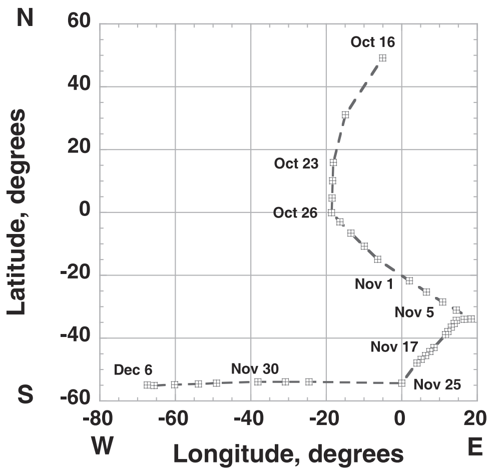

Figure 1. R/V Akademik Sergey Vavilov cruise track.

optical depth and water vapor content [*Morys et al.*, 2001]. Direct sun measurements are acquired in five spectral channels at 340, 440, 675, 870, and 940 nm. The instrument has built-in pressure and temperature sensors. To obtain the time of measurements and geographical position of the ship a GPS was connected to the sunphotometer. The instrument was calibrated at the NASA Goddard Space Flight Center against the AERONET reference CIMEL Sun/sky radiometer. The estimated uncertainty of the optical depth in each channel did not exceed plus or minus 0.02, which is slightly higher than the uncertainty of the AERONET field (not master) instruments, as shown by *Eck et al.* [1999]. Aerosol optical depth was retrieved by applying the AERONET processing algorithm (Version 2) to raw data.

[7] The measurements were carried out when the solar disk was free of clouds. The number of measurements averaged into one data point (a series) was not less than 5 during a three-minute period. The number of series during the day varied from 1 to 33. Arithmetic and geometric daily averages of optical depth (compared to avoid sampling biases [*O'Neill et al.*, 2000]) agree within 0.005 or less.

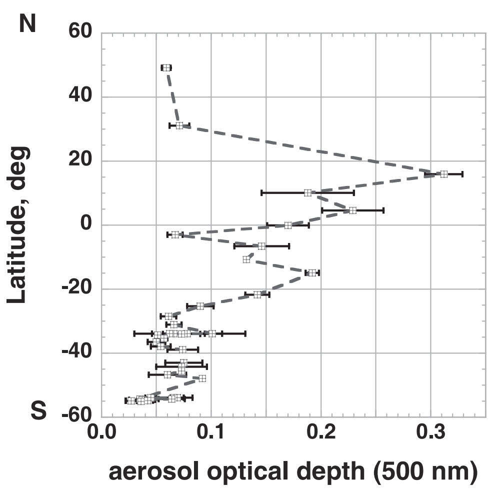

Figure 2. Latitudinal distribution of aerosol optical depth. The horizontal bars indicate plus or minus one standard deviation.

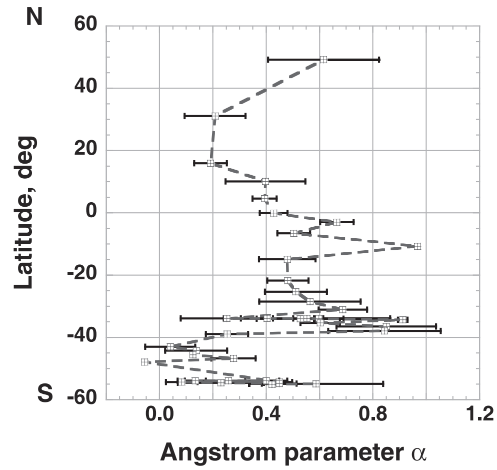

Figure 3. Latitudinal distribution of the Angstrom parameter. The horizontal bars indicate plus or minus one standard deviation.

3. Results

[8] Temporal and latitudinal distribution of the daily averaged aerosol optical depth at 500 nm and Angstrom parameter α (based on 3 wavelengths 440, 675 and 870 nm) are presented in Figures 2 and 3. In order to provide a common basis for comparison with previous results we calculated aerosol optical depth at 500 nm using log-linear interpolation between channels 440 and 675 nm.

4. Conclusions

[16] The principal conclusions from our work can be summarized as follows:

[17] 1. It was found that atmospheric aerosol optical parameters (τ_a(500 nm) $\sim$0.04–0.08 and $\alpha \sim$ 0.0–0.4) in the Southern Atlantic between 34° S and 55° S are close to other remote oceanic areas (for example, high latitude Northern Atlantic, Southern and Tropical Pacific, and South Indian Ocean [*Matsubara et al.*, 1983; *Volgin et al.*, 1988; *Smirnov et al.*, 2002, 2003; *Wilson and Forgan*, 2002; *Shinozuka et al.*, 2004; *Quinn and Bates*, 2005]).

[18] 2. Almost 60% of satellite retrieved optical depths, although highly correlated with the sunphotometer measurements (R = 0.85–0.99), are generally higher by 0.02–0.07, depending on sensor (see Figure 5). A wide range of factors can be responsible for that but we do not discuss them in the current study. The GOCART model calculated aerosol optical depths, on the other hand, are less correlated with sunphotometer measurements (R = 0.59), and, despite the overall bias, about 30% agree within ±0.01.