On the long-term variation of stratospheric aerosols
成層圏エアロゾルの長期変動

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Abstract
Stratospheric Aerosol and Gas Experiment (SAGE) II data at multiple wavelengths were analyzed to investigate the long-term variation of the stratospheric aerosols. By 1999, the stratospheric aerosol extinction was as low as 10^{-4}/km at 20 km, the lowest value recorded in the entire period of SAGE-II observations. The time variation of the extinction coefficients was compared with the Ångstöm parameter that is a good indicator of particle size.　A clear anti-correlation was found between the extinction and the Ångstöm parameter after the eruption of Mt. Pinatubo. The distinguishing negative correlation is a characteristic feature of decay periods following volcanic eruptions. A clear spatial anti-correlation was also found between the two parameters even in the background period, which suggests the particle growth/diminish along with meridional transport.

Introduction

The optical properties of stratospheric aerosols are widely known to affect the global radiation balance.　Such effects are noteworthy after major volcanic eruptions. Radiative forcing by tropospheric aerosols is also an important factor in determining the Earth's radiative balance. Recent studies deduced the optical properties of the tropospheric aerosols using nadir satellite sensors [e.g., Nakajima and Higurashi, 1998].　However, tropospheric optical thickness derived from satellite measurements would be overestimated if the stratosphere were disturbed.　Thus, it is critical to understand when the effect of Mt. Pinatubo on the atmospheric optical thickness was significant.

In this study, we analyzed SAGE-II aerosol extinction data at multiple wavelengths from January 1985 through December 1999.　This includes a later period than that analyzed by Thomason et al. [1997].　We present the time variation of the extinction coefficient, and changes in particle size as indicated by changes in the Ångstöm parameter.

Analysis method

SAGE II has measured aerosol extinction at four wavelengths, (1.019, 0.525, 0.452, and 0.386 μm), at altitudes from 10 to 40 km, using solar occultation techniques since 1985. SAGE-II has near-global coverage, providing daily data for about 30 events at height intervals of 0.5 km.

We used the extinction data at longer three wavelengths of version 6.0 in this analysis. All of the data were averaged for each five-degree latitude band, at each altitude, and for each month. All data with more than 80% relative error were ignored. The extinction coefficients were averaged and computed every five degrees from 80N to 80S where the number of measurements exceeded ten per grid. The wavelength dependence of the extinction was approximated as

$$\sigma = \sigma_0 \lambda^{-\alpha} \qquad (1)$$

where σ is an extinction coefficient (km^{-1}), λ is wavelength (microns), and α is the Ångstöm parameter. The Ångstöm parameters were derived from all events, and are averaged for the five-degree latitude bands. The wavelength dependence on extinction in Eq. (1) was satisfied for most of the wavelength data, although there were some exceptions, especially after the eruption of Mt. Pinatubo.

Hayashida and Horikawa [2001] discussed the validity of Ångstöm parameter as an indicator of particle size. They showed that there is a good correlation between the Ångstöm parameter and the mode radius based on simulation. Comparisons of the Ångstöm parameter with the effective radius obtained by the method of Yue [1999], and the mean radius derived from simple Mie-calculations proved that the Ångstöm parameter is an effective indicator of particle size.

Results and Discussion

Figure 1 shows that the long-term variation of the extinction of 1.02 μm with the Ångstöm parameter. The extinction coefficient continued to decrease after 1997, when the WMO [1998] comparison was made. The unusually prolonged period of disturbance following the Pinatubo eruption was caused by the large amount of sulfate that was injected into the stratosphere. By 1999, the stratospheric aerosol extinction was as low as 10^{-4} /km at 20.5 km, the lowest value in the entire SAGE-II observation record.

Hayashida and Horikawa [2001] presented a clear anti-correlation between the extinction coefficient and Ångstöm parameter during decay period. Immediately after the eruption in 1992, extinction was high and the Ångstöm parameter was low, the opposite of conditions during the background period. In 1999, all data scatter in the range reflecting seasonal variation during a background period, and do not show a negative correlation.

When examined more closely, in 1999 the Ångstöm parameter shows a latitudinal gradient even in the background period. Figure 2 is an example of latitude-height cross section. Although the classic theory of aerosol microphysics depicts growth to 'mature particles' in a poleward meridional circulation, this study suggests that particles diminish in size. Future studies should consider other microphysical processes, such as evaporation, as well as meridional transport.

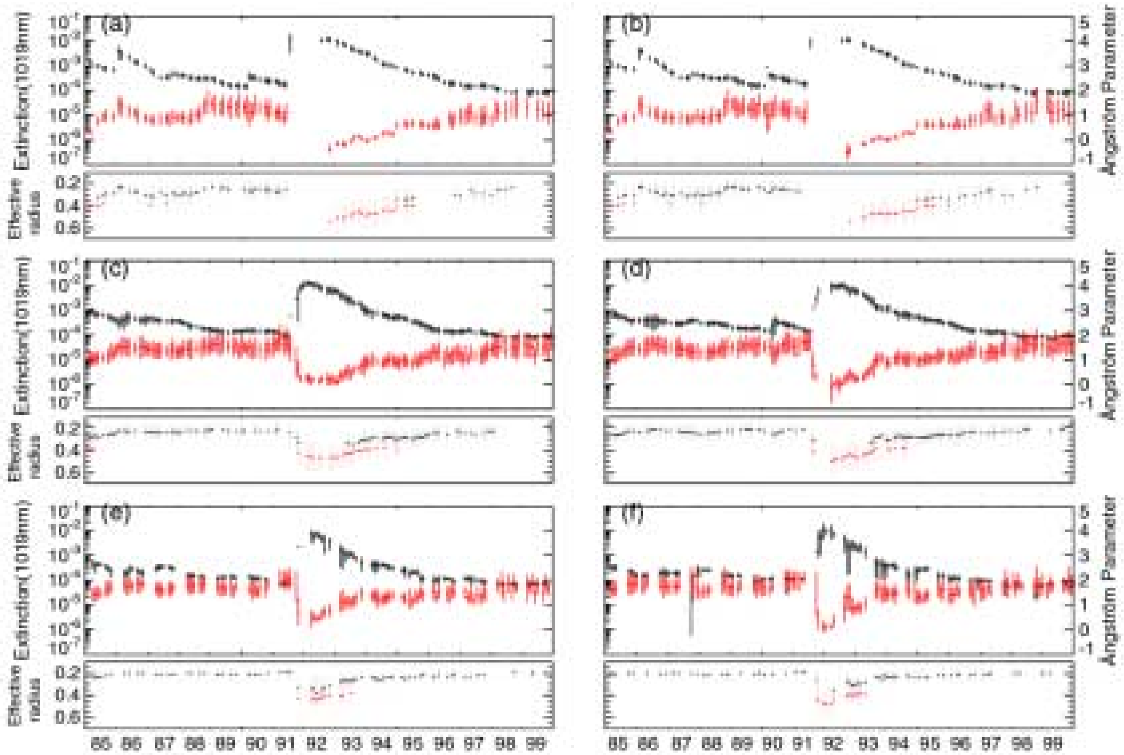

Figure 1

Time series of the 1.02-μm extinction coefficient at 20-km altitude, observed with SAGE II (I). Ångstöm parameters are also plotted in the same panel (II). The panels are for (a) 0-5N, (b) 0-5S, (c) 30-35N, (d) 30-35S, (e) 55-60N, and (f) 55-60S. Lower panels indicate time series of the effective radius derived from Yue's method [Yue, 1999]. All data are plotted with one-sigma error bars. The effective radius is inversely plotted to compare with the parameters.

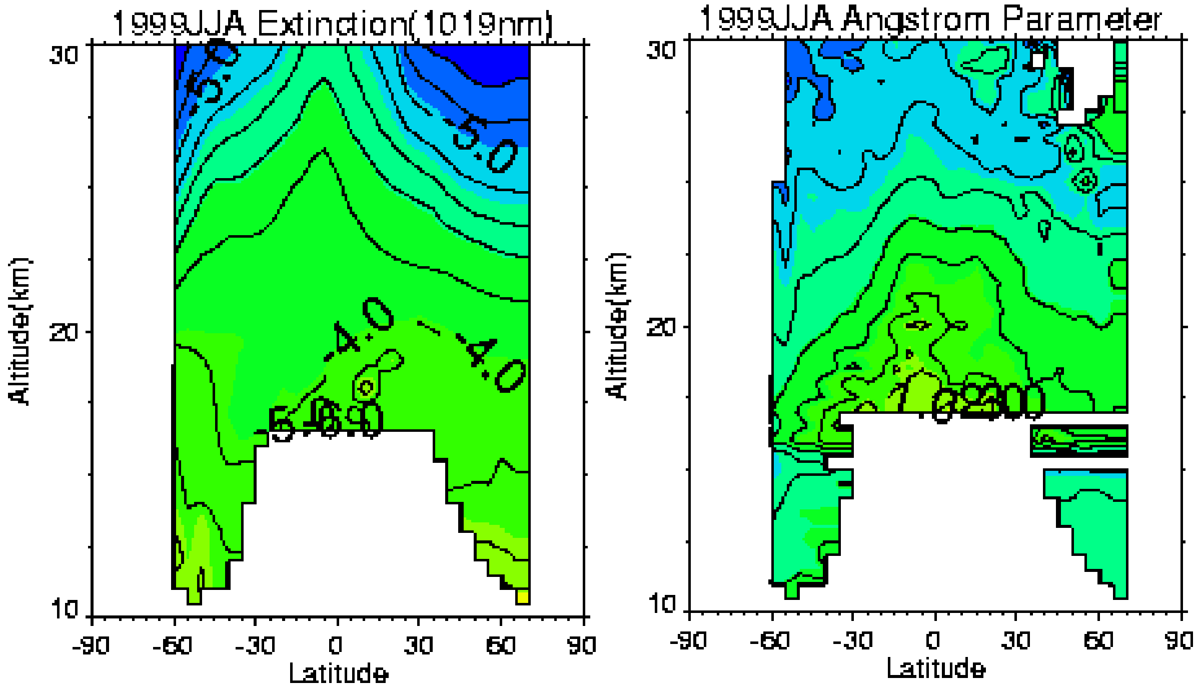

Figure 2

Latitude-height cross sections of the extinction at 1.02 µm (left: The contours are indicated in logarithm of /km) and exponent (right) for three-month average in NH summer in 1999. There is a clear latitudinal gradient in Ångstöm parameter. The anti-correlation between the extinction and Ångstöm parameter is again apparent.

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