

Interactive comment on “Steady-state aerosol distributions in the extra-tropical, lower stratosphere and the processes that maintain them” by J. C. Wilson et al.

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Received and published: 17 May 2008

General comments

This paper presents observations of aerosol size and gas-phase tracers collected by the authors between 1992 and 2004. The authors analyze their wealth of data using novel methods to answer or address a number of highly relevant scientific questions, including the following:

- (1) What are the sources of sulfate aerosol in the upper and lower stratosphere?
- (2) What is the extent of stratosphere-troposphere exchange in the extra-tropical low-

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ermost stratosphere?

(3) What is the source of discrepancy between global microphysical models and observations aerosol extinction and OCS?

(4) What size distributions and total abundances are typical of non-volcanic and post-Pinatubo sulfate in different regions of the stratosphere, and when did conditions return to background following the eruption?

The article is well structured and clear, the conclusions are substantial, and the data presented will be of interest to the scientific community, and particularly useful for model validation. The paper should be published with the technical corrections listed below. I have also included minor specific comments that may warrant attention at the authors' discretion.

The authors use measurements of N₂O as a proxy for age of stratospheric air to discern the evolution of stratospheric sulfate abundance and size distributions. They demonstrate the utility of this proxy with additional simultaneous observations of CO₂, CH₄ and N₂O. By dividing their size distributions into 5 groups depending on N₂O (Fig. 4), they show convincingly that dry aerosol size distributions were greatly perturbed immediately following the 1992 eruption of Pinatubo, remained perturbed through 1997, and returned to a non-volcanic steady state throughout 1999-2004. They support this conclusion with Fig. 5, showing total abundance of sulfate vs. N₂O in volcanic, intermediate, and background conditions. The loss of equivalent mixing ratio for sulfate at high N₂O values shown in this figure establishes the importance of sedimentation in the "overworld".

The authors present a sophisticated analysis of the source and loss terms maintaining sulfate abundance at various N₂O levels. Their analysis shows clearly that the OCS oxidation and photolysis source and sedimentation loss are responsible for the maintaining sulfate for N₂O > ~225 ppbv, equivalent to an age of air greater than ~3.5 years. For the lower stratosphere, an additional source term is apparent. The authors reason-

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ably identify this source as tropospheric SO₂, which is commonly observed in the free troposphere in the 40-80 ppbv range.

The authors use their analysis to address the discrepancies between models and observations shown in the SPARC Assessment of Stratospheric Aerosol Properties, Chapter 6 (Weisenstein and Bekki, 2006). Three of the five models in that study over-predicted OCS at 65N between 15 and 20 km, and four of the five overpredicted aerosol extinction in the same altitude region at 45N. Surmising that model transport is at fault, one can easily conclude from the SPARC analysis that increasing the age of air in the lower stratosphere might solve both problems. The authors here use their empirical relationships of N₂O to OCS and sulfate to estimate that one year should be added to the age of air in these models. This analysis should be of great benefit in improving and validating these and other models.

Specific comments

The concept of volume mixing ratio (ppbv) for sulfate might confuse some readers, since the sulfate is condensed in liquid aerosol, and thus takes up a much smaller volume than it would if it were in the gas phase. The authors may wish to clarify early in Section 3 that they mean an "ppbv equivalent," i.e. the volume mixing ratio that sulfate would have if it were in the gas phase.

On p. 3675, line 7, the authors state "The balance holds in each of these control volumes and amounts of H₂SO₄ equivalent to the steady state loadings are condensed and sedimented out in roughly one year." It was not clear to me where the timescale of one year comes from in this analysis. Could the authors explain how this is derived?

Technical corrections

p. 3677, line 12: Should "67 N" should be "65 N"? The SPARC report does not show an OCS comparison at 67 N.

p. 3677, line 14: Should "65 N" should be "45 N"? The SPARC report presents vertical

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profiles of extinction at 45 N, but also shows extinction at 15-20 km across all latitudes. However, the authors mention the profiles at 45 N on page 3676, leading me to think that is what the figure to which they refer.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 3665, 2008.

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