A Fast Stratospheric Aerosol Microphysical Model

S. N. Tripathi[1], R. G. Grainger[1], H. L. Rogers[2]
[1]Atmospheric, Oceanic and Planetary Physics, Department of Physics, University of Oxford, Oxford, OX1 3PU, UK
[2]Department of Chemistry, Cambridge University, CB2 1HE, UK
tripathi@atm.ox.ac.uk

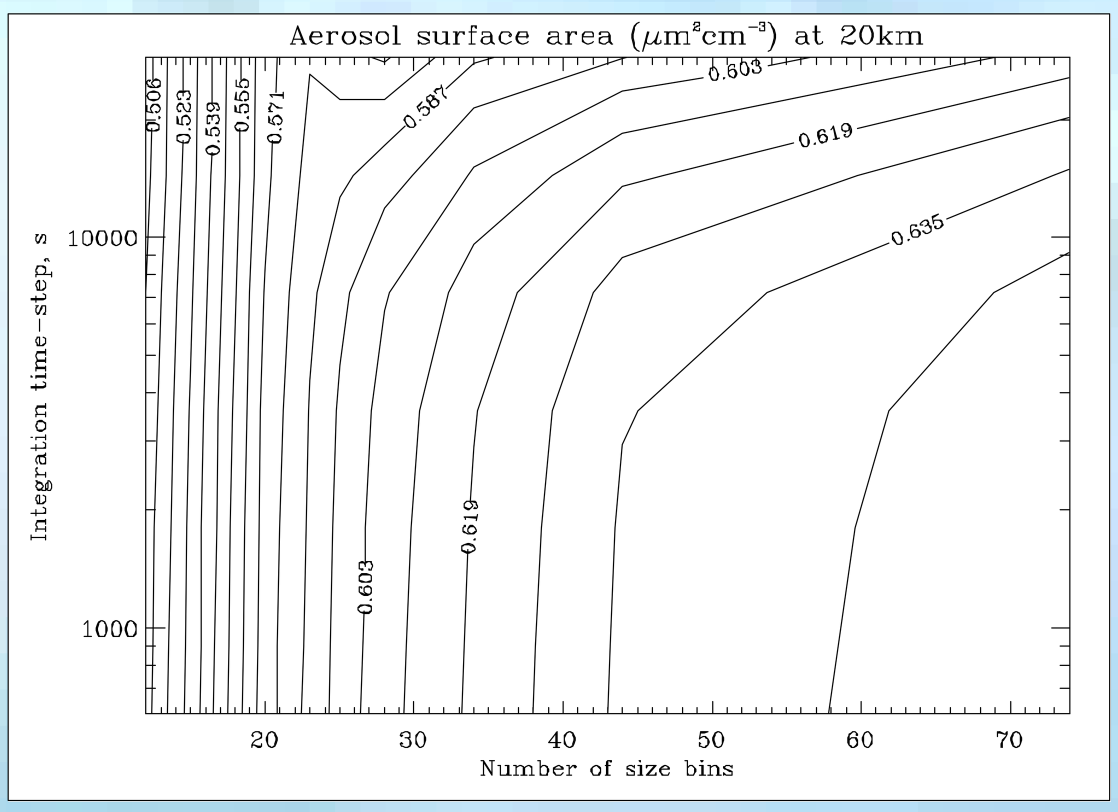
INTRODUCTION

Stratospheric aerosols can affect the global climate system in a variety of ways. These aerosols play a significant role in the Earth's radiative balance and provide a surface for heterogeneous chemistry, which is important for ozone loss in the middle atmosphere. These different atmospheric mechanisms are enhanced when the background aerosol layer is perturbed by civil transport aircraft. There is a need for 3-D simulations of the effects of aircraft emissions on background stratospheric aerosols including radiative and chemistry effects. Global studies are important because of the complex interactions between radiation, transport, chemistry and aerosol microphysics. In this poster we describe a microphysical box model which has been developed for inclusion in the SLIMCAT-global chemical/dynamic/radiative model. Computer processing time and memory use is an important issue in global simulations of atmospheric processes. Keeping that in mind we use non-iterative solutions of the growth and coagulation equations in our microphysical model.

Model

The present microphysical model simulates particle formation by homogeneous nucleation, growth of particles by sulphuric acid and water vapour condensation, Brownian coagulation among the particles and sedimentation. Condensation and coagulation are coupled in a time-split manner (Tripathi et al., 2003.).

Results



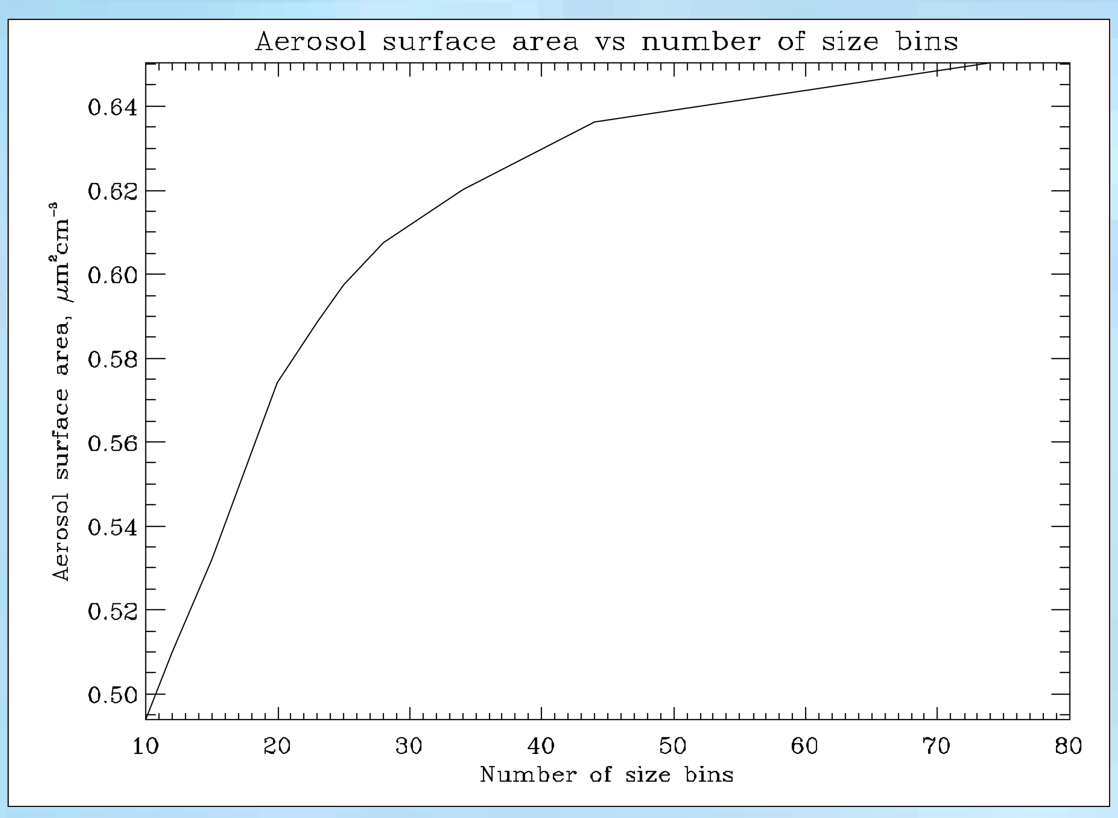


Figure 1 (a) Aerosol surface area plotted as function of size bins used and integration time-step. (b) Aerosol surface area versus size bins for an 1800 s time-step.

We have performed a number of sensitivity studies to examine the choice of the number of size bins on the predicted size distribution parameters. Aerosol surface area is an important input for chemical models. Figure 1 (a) plots the background aerosol surface area as a function of the number of size bins and the integration time-step. It can be seen that aerosol surface area lies between 0.50-0.65 $\mu m^2 cm^{-3}$. This value is comparable to those recommended for heterogeneous chemical reactions of atmospheric importance (WMO, 1992). It can be seen that number of size bins have a pronounced effect on the calculated aerosol surface area. From figure 1 (b) one notices that surface area decreases from 0.65 to 0.50 $\mu m^2 cm^{-3}$ as the number of bins decreases from 75 to 10.

Validation

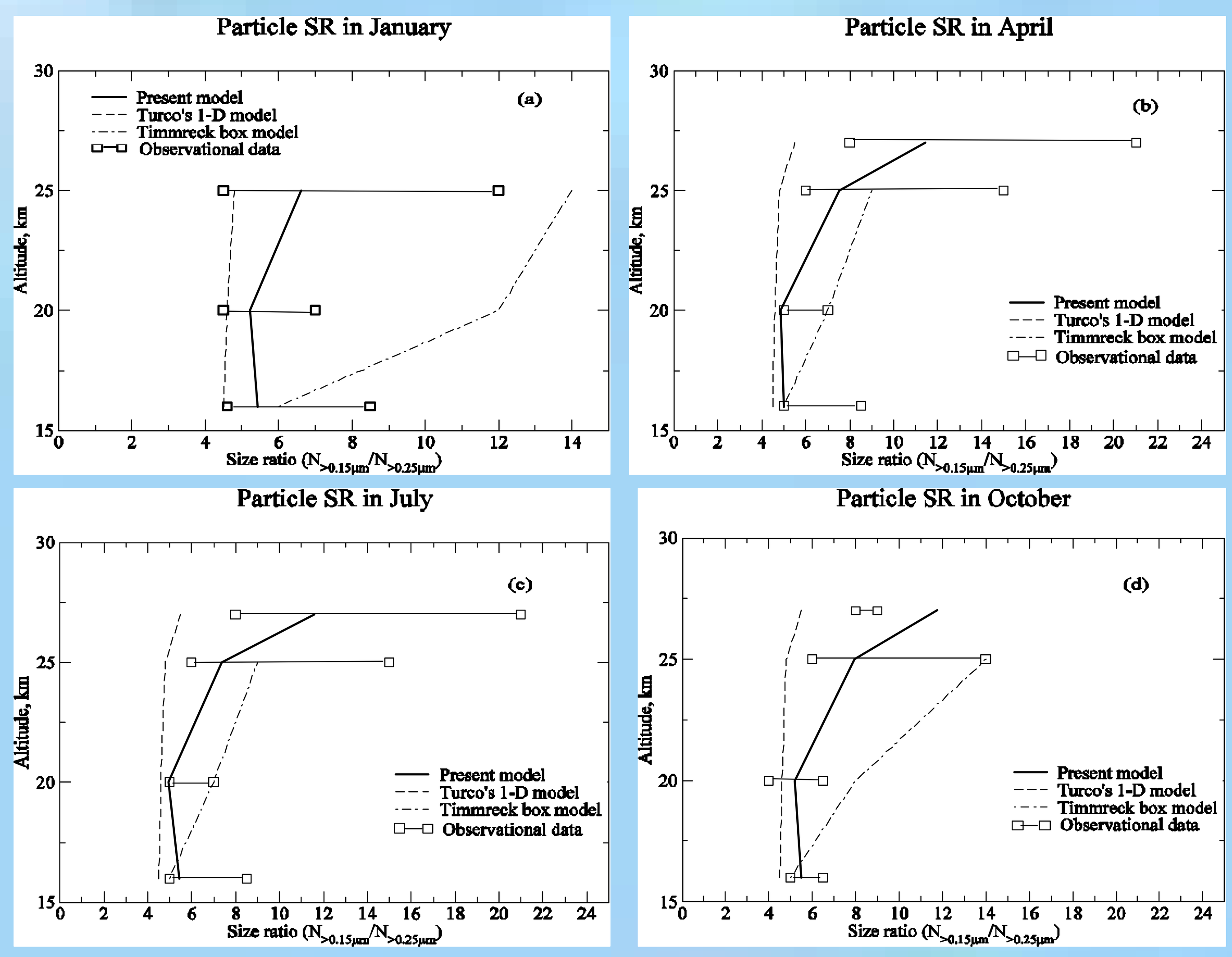


Figure 2 (a) Numerical values of particle size ratio (SR) as a function of altitude for January conditions. Also shown are the observed values of SR taken from the measurements of Hofmann and Rosen (1981) and modelled values from Toon et al. (1979) and Timmreck and Graph (2000). (b) Same as (a) except for April conditions. (c) Same as (a) except for July conditions. (d) same as (a) except for October conditions.

In figures 2 (a) to (d) we plot model predicted size ratio ($N_{0.15}/N_{0.25}$) as a function of altitude. It is clear that modelled values of size ratio match well with the observed values taken from Hofmann and Rosen (1981). We also notice that the modelled values of size ratio do not show large variations with altitude as observed by Hofmann and Rosen (1981) and predicted by Toon et al. (1979) up to 25 km. At very high altitude an increase in SR can be seen. Comparing figures 2 (a) to (d) we do not see large seasonal variations in the size ratio which is consistent with the earlier 1-D (Toon et al., 1979) and 0-D (Timmreck and Graph, 2000) model predictions. Furthermore, the total number concentrations of particles are always between 4-8 cm^{-3} which falls within the range reported by Weisenstein et al. (1997), who studied stratospheric aerosols using a two-dimensional model.

Conclusions

A fast microphysical model for the stratosphere is developed which simulates homogeneous nucleation of sulphuric acid-water aerosols, condensational growth, coagulation among the particles and sedimentation removal. The model uses a non-iterative scheme to solve the final number concentration of particles undergoing these processes; this is computationally very fast and makes the model ideal for importing into 3-D global models. The present model has been used to simulate background stratospheric aerosol size distribution. The modelled size distribution parameters are comparable to the range of observed and reported values.

Future work

- To assess the effects of ions on particle formation and their role in the evolution of particle size distribution after volcanic eruptions.
- To modify the present binary aerosol microphysical model to simulate ammonium sulphate particles.

References

Hofmann, D. J., and J. M. Rosen, On the background stratospheric aerosol layer, *J. Atmos.Sci.*, **32**, 1446-1456, 1981.
Timmreck, C., and H. F. Graph, A microphysical model for simulation of stratospheric aerosol in a climate model, *Meteorologische Zeitschrift*, **9**, 263-282, 2000.
Toon, O. B., R. P. Turco, P. Hamill, C. S. Kiang, and R. C. Whitten A one-dimensional model describing aerosol formation and evolution in the stratosphere: II, Sensitivity studies and comparison with observations, *J. Atmos Sci*, **36**,718-736, 1979.
Tripathi, S. N., Grainger, R. G. and H. L. Rogers, A fast microphysical aerosol model: Development and validation. In prep .for *J. Geophys. Res*., 2003.
Weisenstein, D. K., P. K. Yue, G. K. W. Ko, N. D. Sze, J. M. Rodriguez, and C. J. Scott, Two-dimensional model of sulphur species and aerosol, *J. Geophys. Res*., **102**, 13019-13053, 1997.
World Meteorological Organisation, Scientific Assessment of Ozone Deplteion:1991, *WMO Rep.* 25, Geneva, 1992.