Use of GMI to Study Tropospheric and Stratospheric Bromine Budgets
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Aerosol 2-D Intercomparison wrap-up/publication

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Motivation for Bromine Study

Measurements of stratospheric BrO imply Br_y concentrations that are 4-8 pptv greater than models which include only CH_3Br + halons [Salawitch et al., 2004]

Sensitivity studies show that an additional 4-8 pptv of Br_y has a large effect on stratospheric ozone trends, particularly in times of enhanced aerosol loading [Salawitch et al., 2004; WMO, 2006]

GMI Stratosphere-Troposphere (Combo) model provides a unique tool to address the transport of short-lived gases and their degradation products to the stratosphere

Tropospheric Bry may deplete tropospheric ozone up to 15%, and affect OH, HO_2, and H_2O_2 concentrations up to 20% [Glasow et al., 2004]

Tropospheric Br_y has chemical coupling to DMS and aerosols

Stratospheric effects most important near tropopause where long-lives species produce little Br_y

BrO + ClO reaction amplifies effect of anthropogenic chlorine on stratospheric chemistry

Relevant Compounds and Sources

Compound	Concen.	Source
CH_3Br	9-10 ppt	fumigation, biomass, phytoplankton
$CHBr_3$	0.6-3.0 ppt	phytoplankton, macroalgae
CH_2Br_2	0.8-3.4 ppt	phytoplankton, macroalgae
CH_2BrCl	0.1-0.5 ppt	phytoplankton, macroalgae
$CHBr_2Cl$	0.1-0.5 ppt	phytoplankton, macroalga
$CHBrCl_2$	0.12-0.6 ppt	phytoplankton, macroalgae
$C_2H_4Br_2$	0.3-0.5 ppt	industrial, biogenic?

Relevant Compounds, Emissions, and Lifetimes

Compound	Concen.	emissions	lifetime
CH_3Br	9-10 ppt	112-454 Gg/yr	0.7 yr
$CHBr_3$	0.6-3.0 ppt	200-285 Gg/yr	26 days
CH_2Br_2	0.8-3.4 ppt	55-67 Gg/yr	4 months
CH_2BrCl	0.1-0.5 ppt	2.9 Gg/yr	5 months
$CHBr_2Cl$	0.1-0.5 ppt	4.2-12 Gg/yr	69 days
$CHBrCl_2$	0.12-0.6 ppt	5.5-7.0 Gg/yr	78 days
$C_2H_4Br_2$	0.3-0.5 ppt	77-151 Gg/yr	84 days

Tasks

I. Single species calculations

   I. Run kmg for apropriate chemistry and loss rates

   II. Emission inventories - simple or parameterized by ocean productivity, wind, etc

   III. Comparisons with observations, sensitivity studies, adjust sources

II. Calculation of Br_y

   I. All bromine compound incorporated into Combo GMI model

   II. Br_y removal depends on tropospheric partitioning and solubility

   III. Compare BrO to observations

Tasks, continued

III. Atmospheric Impact Calculations

I. Tropospheric changes in O_3, HO_x, NO_x, DMS

II. Bromine-sulfur interaction

III. Stratospheric calculations for 1980 and 1993 (high aerosol) with and without short-lived compounds

IV. Time-dependent hindcast for ozone trends

Progress

Produced GMI version with simplified chemistry for one bromine compound

$CH_3Br + OH \rightarrow Br_y$

$CH_3Br + O^1D \rightarrow Br_y$

$CH_3Br + Cl \rightarrow Br_y$

$CH_3Br + h\nu \rightarrow Br_y$

O_3, OH, O^1D, Cl treated as constant species read from file

Testing model for CH_3Br, since we can compare results with full Combo GMI model.

Model was working on Halem, but initial conditions and boundary conditions not set properly from the namelist input file.

On Discover, model compiles but runtime errors related to photolysis.

Global 2-D Intercomparison of Sectional and Modal Aerosol Modules

D.K. Weisenstein, J. E. Penner, M. Herzog, and X. Liu

Published in

Atmos. Chem. Phys., 7, 2339-2355, 2007

www.atmos-chem-phys.net/7/2339/2007

Follow-on to the box model intercomparison paper:

Herzog et al., JGR, 109, D18202, 2004

2-D Model Description

Pole to Pole (9.5° resolution), surface to 60km (1.2 km resolution)

2-D advection and diffusion from Fleming et al. [1999] based on NCEP data and satellite observations

2-D parameterized convection from Dvortsov [1998]

Sulfate-water aerosols only covering size range 0.4 nm - 3 μm

Sulfur source gases: DMS, H_2S, CS_2, OCS, SO_2 with constant surface emissions

Aerosol microphysics includes homogeneous nucleation, condensation/evaporation, coagulation, and sedimentation

UMich and AER aerosol modules were “synchronized” via previous box model intercomparison

Table 1: Aerosol Module Versions

Version/Bins	Bin Ratio by volume	Time Step	Run time rel. to AER40
AER150	V_{rat}=1.2	15 minutes	20
AER40	V_{rat}=2.0	1 hour	1.0
AER20	V_{rat}=4.0	1 hour	0.25

Version/Modes	Distribution widths σ_g	Merge Radii	Run time rel to AER40
UMaer-3mA	1.2/1.514/1.78	0.005/0.05	0.7
UMaer-3mB	1.2/1.514/1.6	0.005/0.05	0.7
UMaer-4m	1.3/1.6/1.6/1.45	0.001/0.01/0.1	1.1

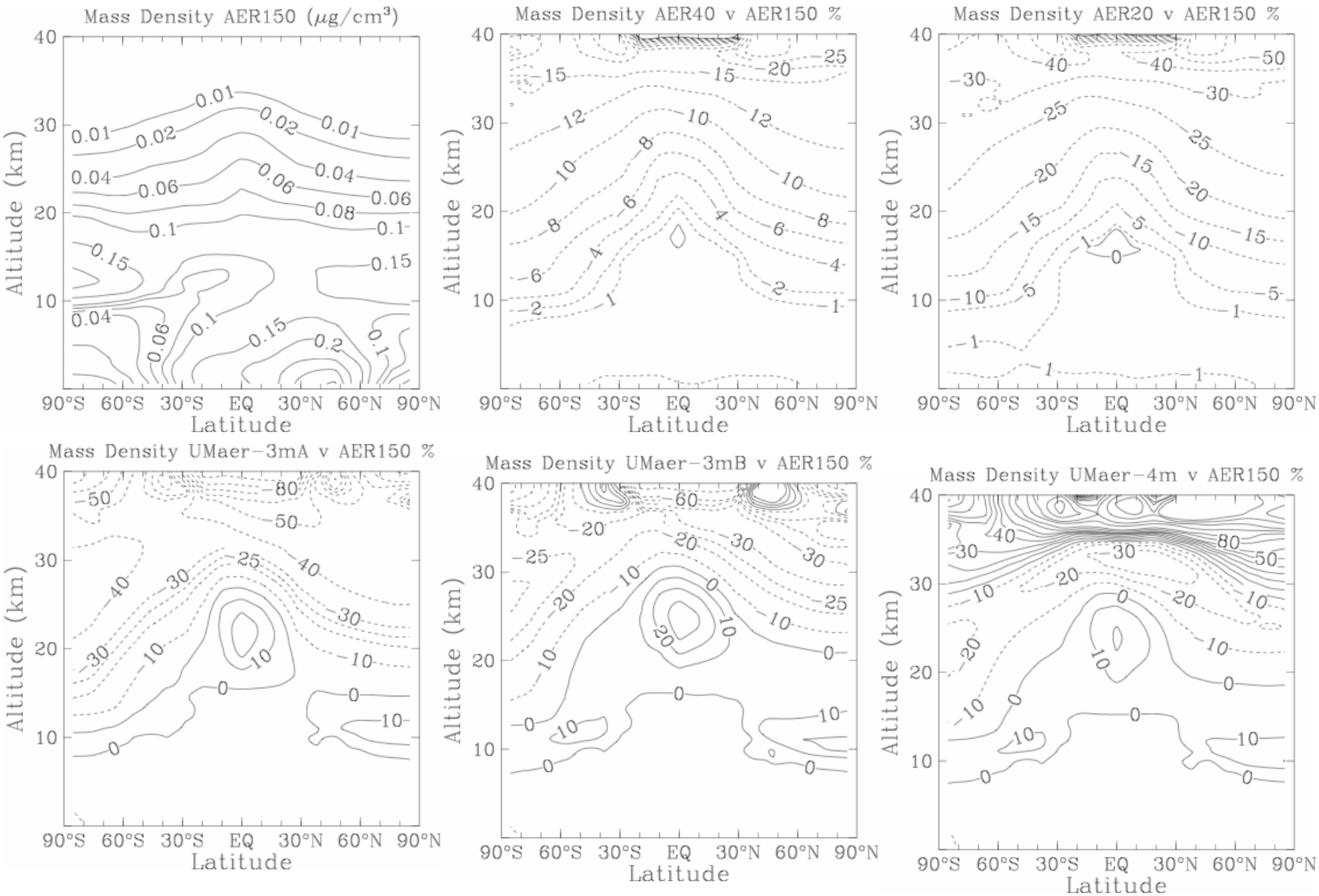

Figure 1: Calculated annual average aerosol mass density for the AER150 model and percent changes between the AER150 model and other model versions for the background nonvolcanic simulation.

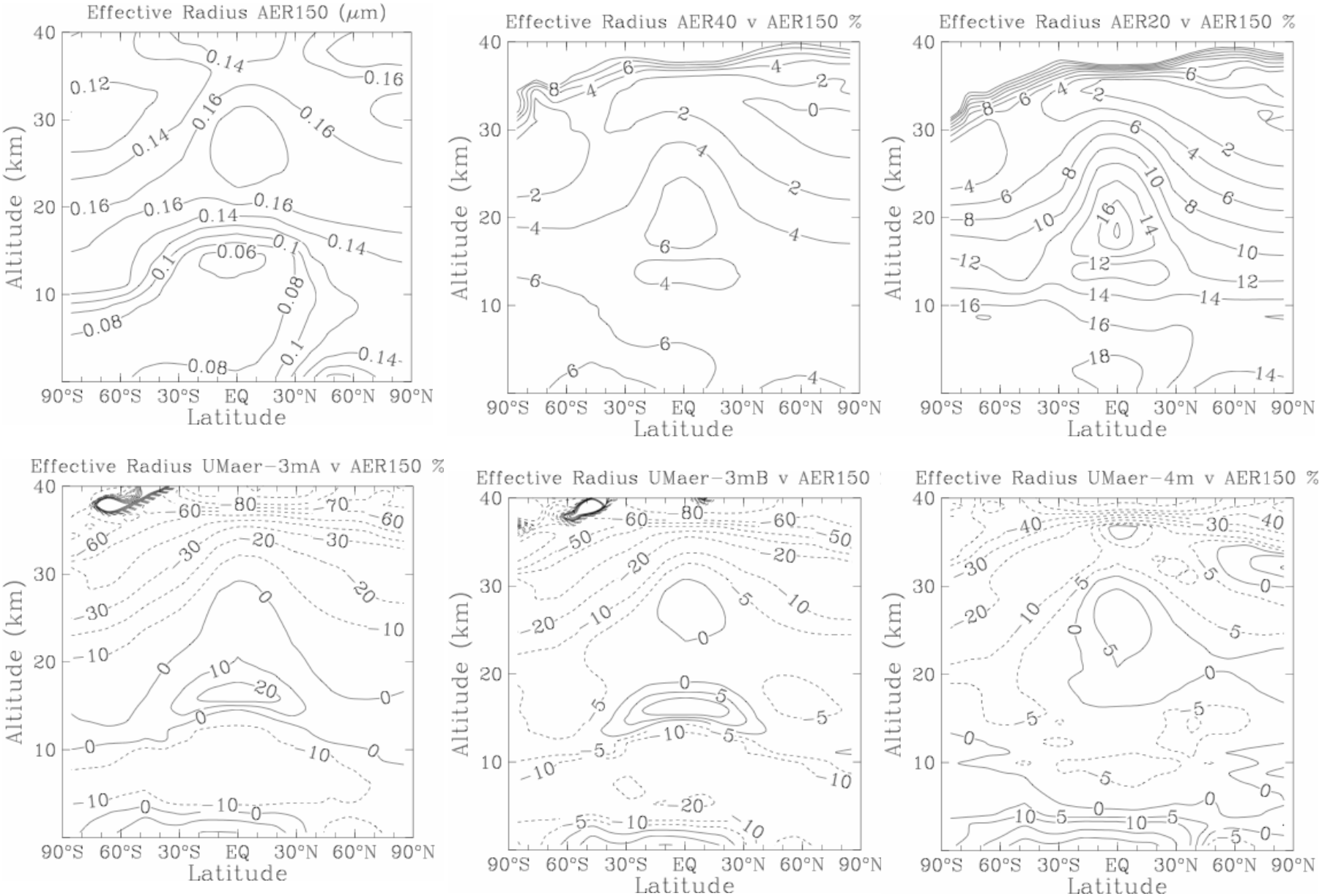

Figure 2: Calculated annual average effective radius for the AER150 model and percent changes between the AER150 model and other model versions for the background nonvolcanic simulation.

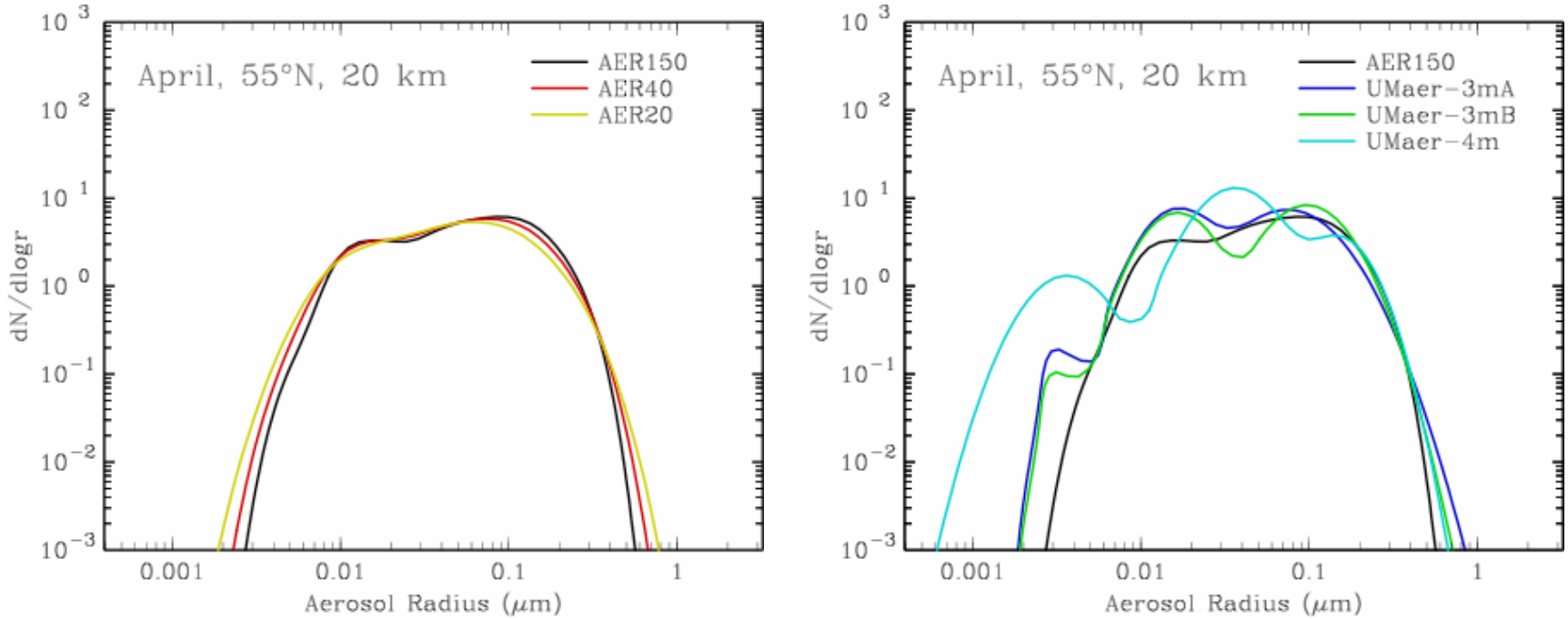

Figure 3: Calculated aerosol size distribution in April at 55ºN and 20 km for the background nonvolcanic scenario.

Pinatubo simulations

20 MT of SO_2 is injected on June 14, 1991 into the region from 5ºS to 15°N and from 16 to 29 km

Reaction of SO_2 with OH produces sulfuric acid which condenses into particles, increasing particle size and aerosol mass loading

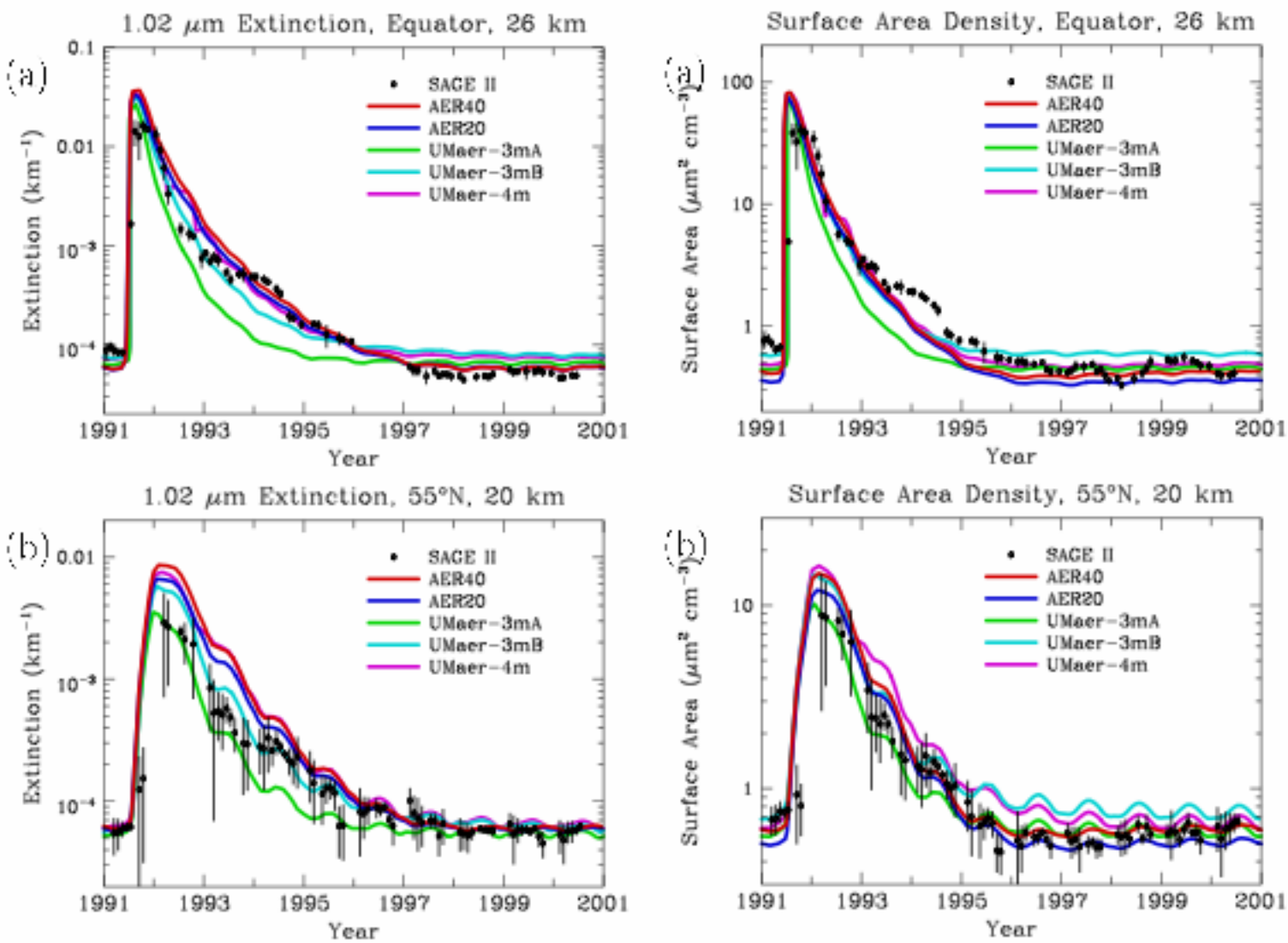

Figure 4: Time evolution of aerosol extinction and surface area density following the 1991 eruption of Mt. Pinatubo. SAGE II data version 6.1 shown for comparison.

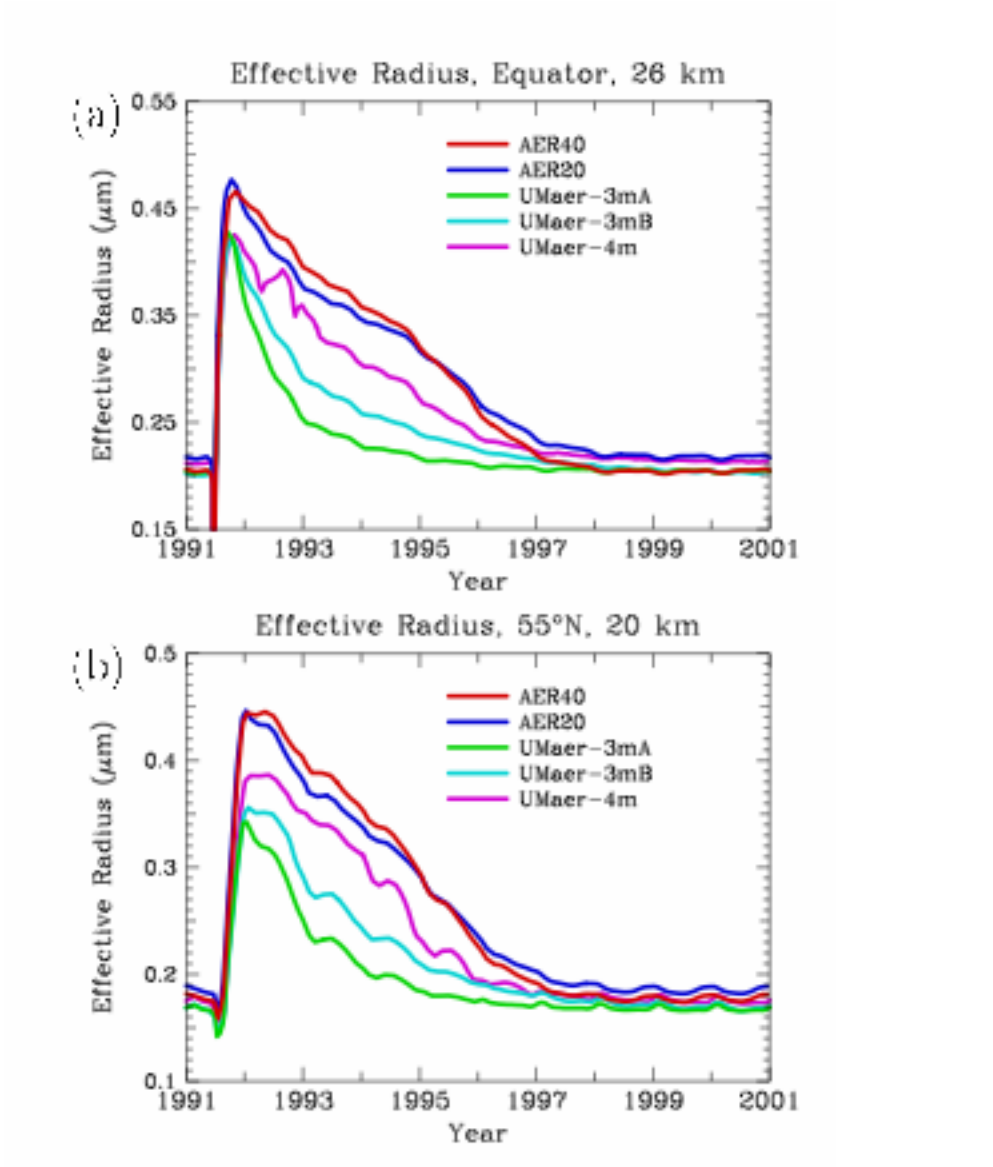

Figure 5: Time evolution of aerosol effective radius following the 1991 eruption of Mt. Pinatubo.

Conclusions

Global aerosol burdens for all models are within 7%, though the stratospheric burden above 25 km can vary by 20%

For modal models, the width of the largest mode impacts sedimentation rates and volcanic removal rates

The time evolution of extinction and surface area under volcanic conditions is adequately modeled by all versions except UMaer-3mA, with uncertainty not larger than transport variability

The time evolution of effective radius shows better numerical accuracy from a low-resolution sectional model than a 3 or 4 mode model

Based on numerical accuracy and timing considerations, we recommend that AER40 and UMaer-3mB be incorporated into the stratosphere-troposphere version of GMI. AER20 may replace AER40 in some situations with considerable computational savings