Supplementary Material for "Evaluating the simulated radiative forcings, aerosol properties and stratospheric warmings from the 1963 Agung, 1982 El Chichon and 1991 Mt Pinatubo volcanic aerosol clouds"

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1 Converting Backscatter Ratio to Extinction

The wavelength exponent and aerosol extinction factor are necessary coefficients for calculating extinction from the backscatter ratio. These are obtained from Figures 2 and 4 in Jäger and Deshler (2003a) for four monthly averages (note the published correction for Figure 2 in **?**). As these coefficients are not available for the time of the Agung eruption, we use values for March 1992–October 1993, which represent values from 10 months after the 1991 Mount Pinatubo eruption. As the coefficients are derived considering the temporal evolution of the particle size distribution (PSD), we assume a similar temporal evolution of the Agung PSD here to the period starting 10 months following the Pinatubo eruption.

The calculation for molecular backscatter is from Vega et al. (2017):

$$\beta_{Rayleigh(\lambda,z,\theta)} = 2.938 \times 10^{-32} \frac{P_{(z)}}{T_{(z)}} \cdot \frac{1}{\lambda^{4.0117}} (m^{-1} sr^{-1}) \tag{1}$$

where P is pressure (hPa), T is temperature (K), z is altitude (m), λ is wavelength (m) and $\beta_{Rayleigh}$ is the backscatter coefficient (angular).

The backscatter ratio (BSR) is defined as:

$$BSR = \frac{\beta_{mol} + \beta_{aer}}{\beta_{mol}} \tag{2}$$

where β_{mol} and β_{aer} are molecular and aerosol backscatter, respectively.

In general, the steps used to convert the lidar backscatter to extinction are as follows:

1. Calculate molecular backscatter for MLO using $\beta_{Rayleigh}$ for a given pressure. Here, we use values from US standard atmosphere (Table S1).

2. Calculate the aerosol backscatter (β_{aer}) using:

$$\beta_{aer694} = (BSR - 1) \times \beta_{mol694} \tag{3}$$

where, $\beta aer694$ and $\beta mol694$ are aerosol and molecular backscatter at 694 nm, respectively.

3. Convert aerosol backscatter at 694 nm to 532 nm using:

$$\beta_{aer532} = (\frac{694}{532})^{kb} \times \beta_{aer694} \tag{4}$$

where β_{aer532} is aerosol backscatter at 532 nm or, more generally, from wavelength λ_2 to λ_1:

$$\beta\lambda_1 = (\frac{\lambda_2}{\lambda_1})^{kb} \times \beta\lambda_2 \tag{5}$$

4. Calculate extinction at 532 nm using:

$$EXT_{532} = \beta_{aer532} \times ke \tag{6}$$

where EXT_{532} is the aerosol extinction at 532 nm and ke is the aerosol extinction factor.

Table S1. Standard atmosphere values of pressure, altitude and temperature.

Pressure (hPa)	Altitude (m)	Temperature (°C)	Temperature (K)
120.4	15000	-56.5	216.65
47.5	20900	-55.6	217.55
25.1	25000	-51.5	221.65

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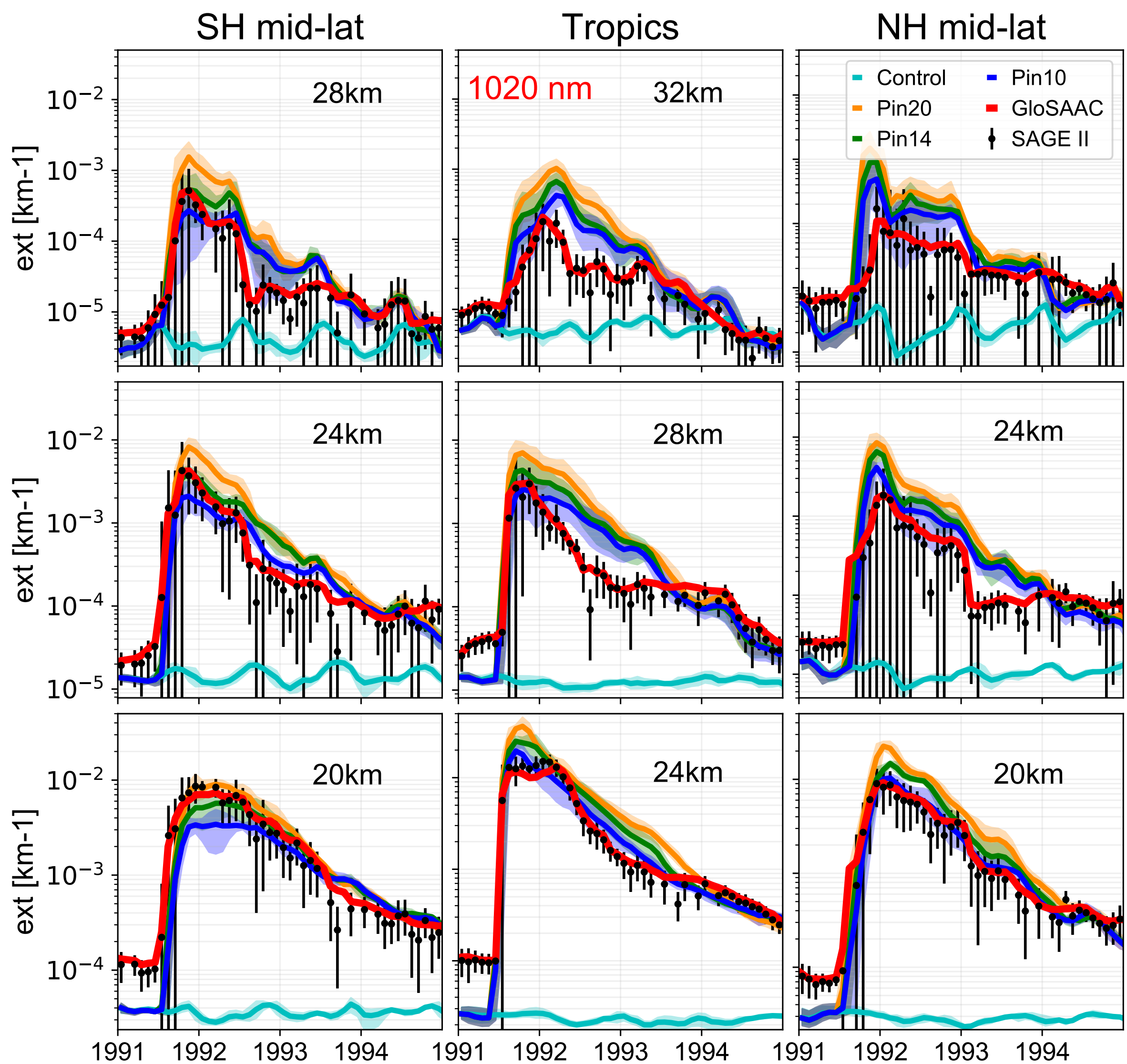

Figure S1. Ensemble mean extinctions (1020 nm) from simulations **Pin00** (aqua), **Pin10** (blue), **Pin14** (green), and **Pin20** (orange). The shaded regions indicate the variability among ensemble members. Extinctions for SH mid-latitudes (35°S – 60°S), tropics (20°S – 20°N), and NH mid-latitudes (35°N – 60°N) are shown in left, middle and right panels, respectively. Mid-latitude extinctions are shown for 20, 24 and 28km, whereas tropical profiles are shown for 24, 28 and 32 km. Monthly mean extinction from SAGE II v7.2 measurements for a given latitude band are shown with black filled circles and vertical lines indicate standard deviation from all the measurements for a given month. Gap-filled extinctions from the GLoSSAC dataset (Thomason et al., 2018) are shown with a red line.

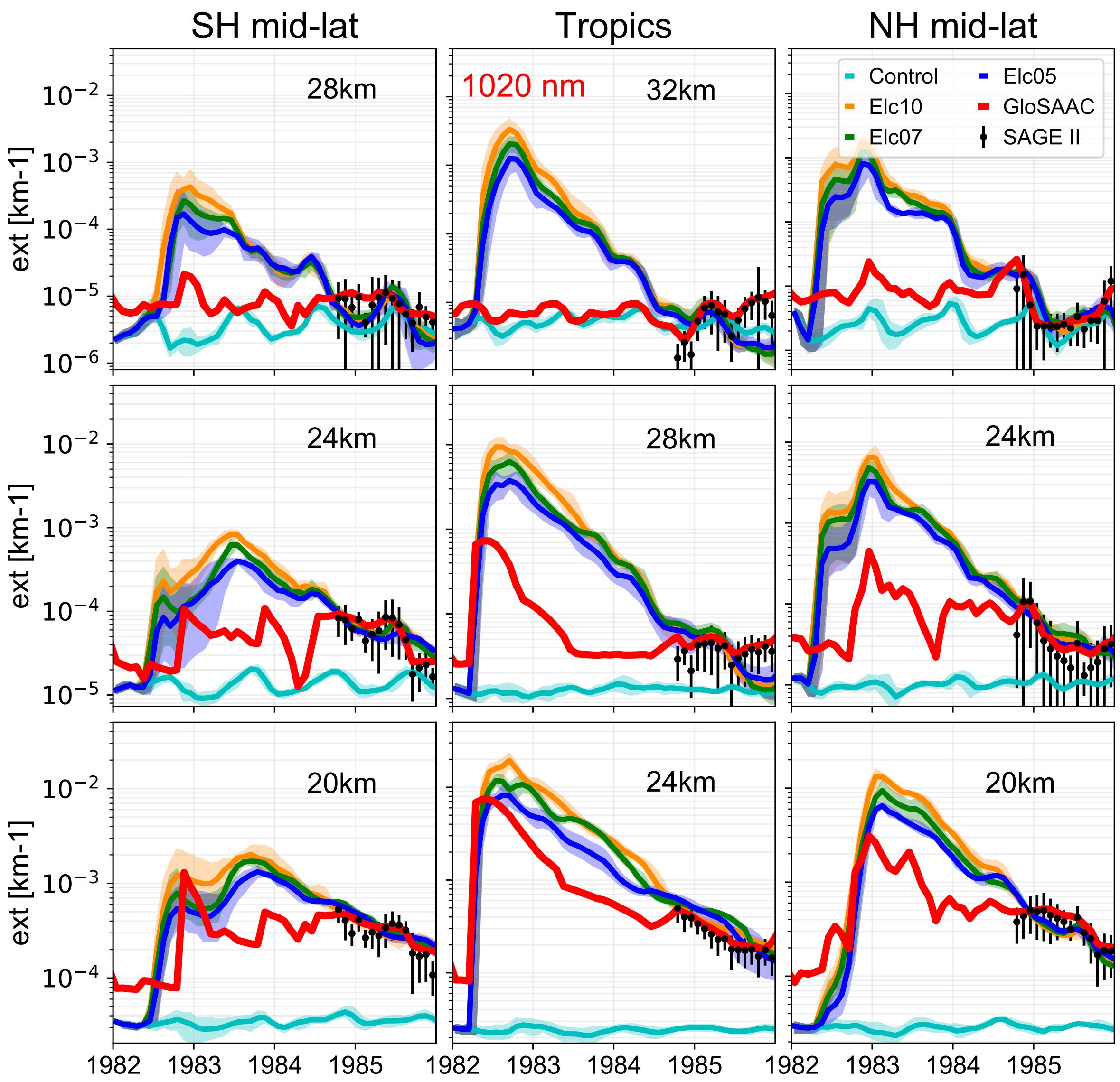

Figure S2. Same as Figure S1 but for the El-Chichon eruption

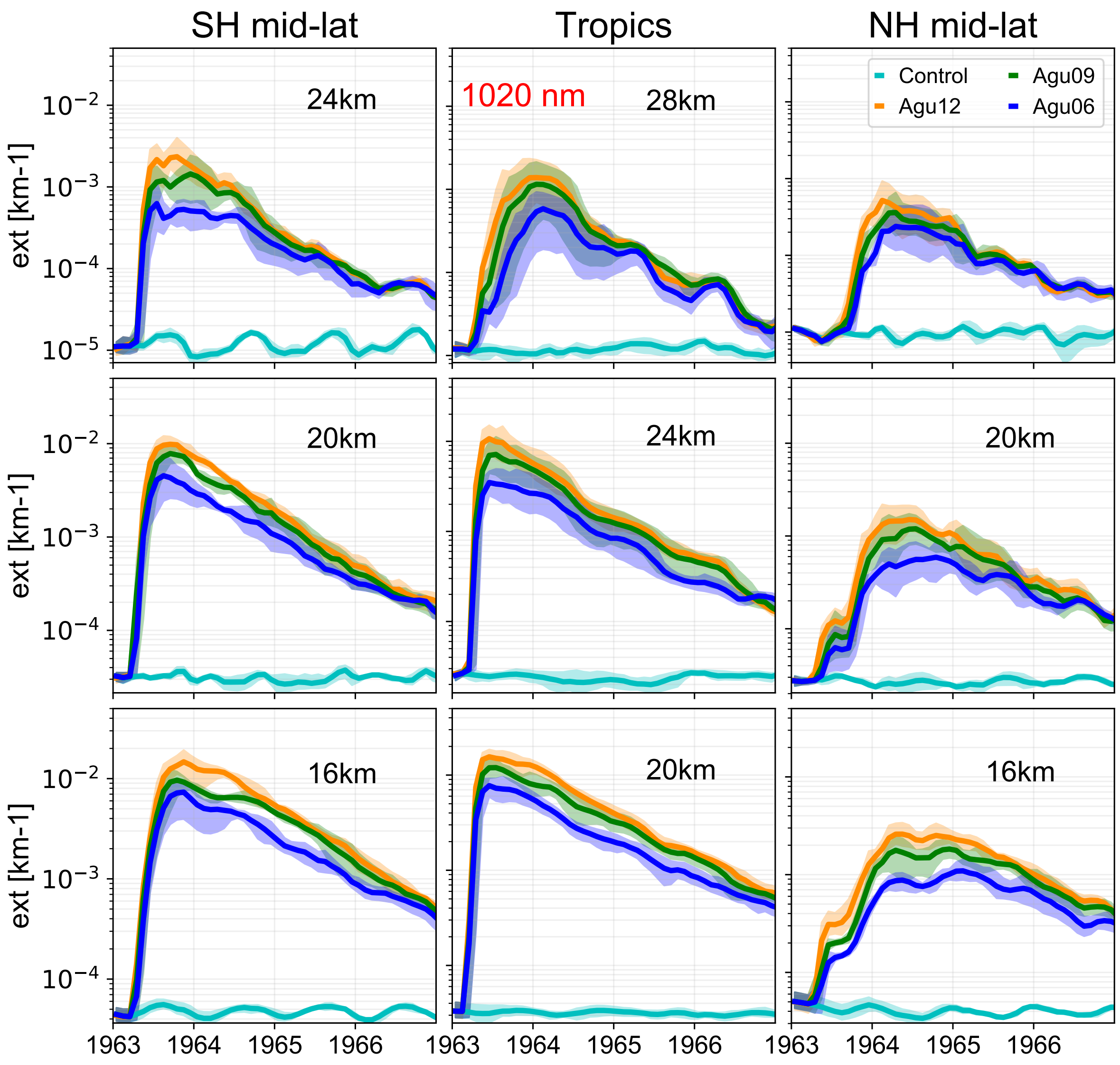

Figure S3. Same as Figure S1 but for the Agung eruption. Extinction at 1020 nm is not available in the evaluation datasets, hence only simulated extinctions are shown.

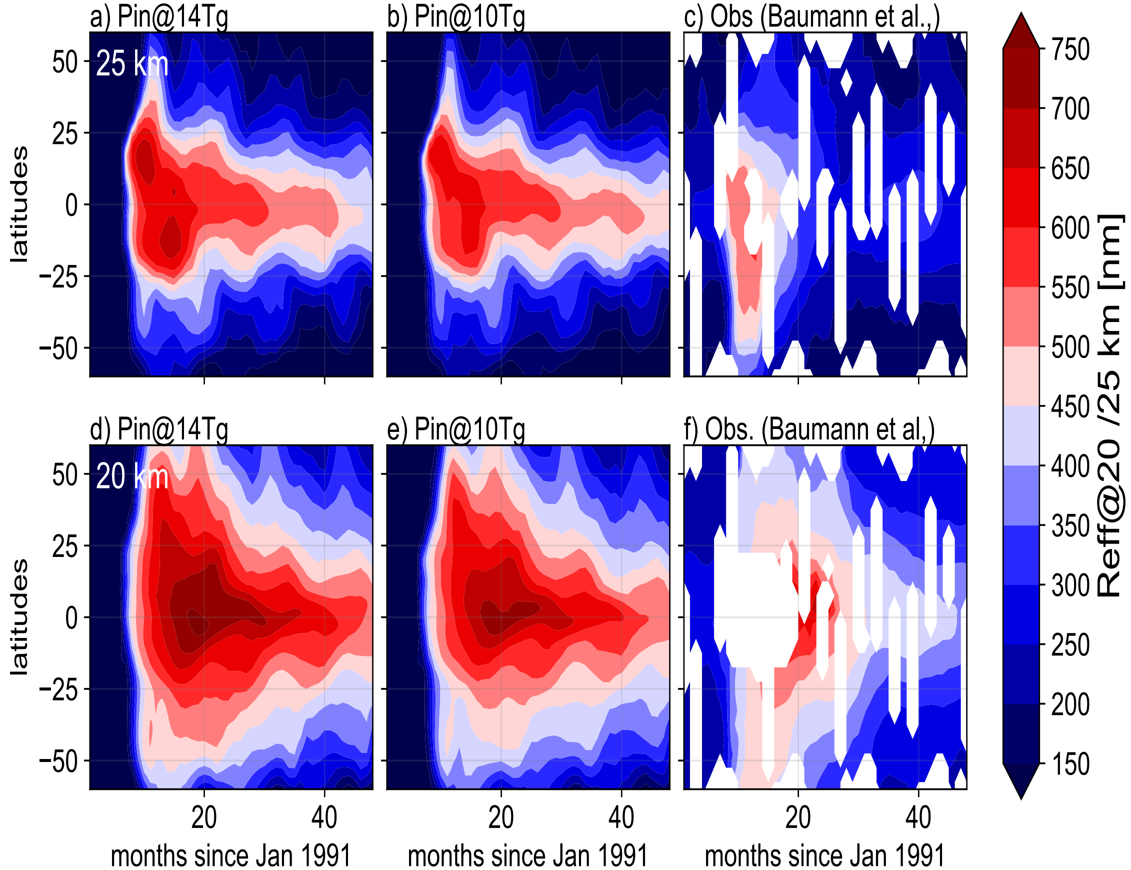

Figure S4. Modelled (from simulations **Pin14** and **Pin20**) and observation-derived (from (Bauman et al., 2003)) effective radii (Reff, in μm) at (a)-(c) 25 km and (d)-(f) 20 km.