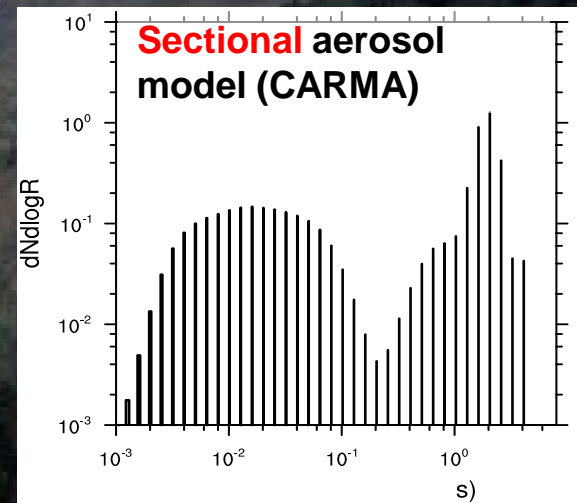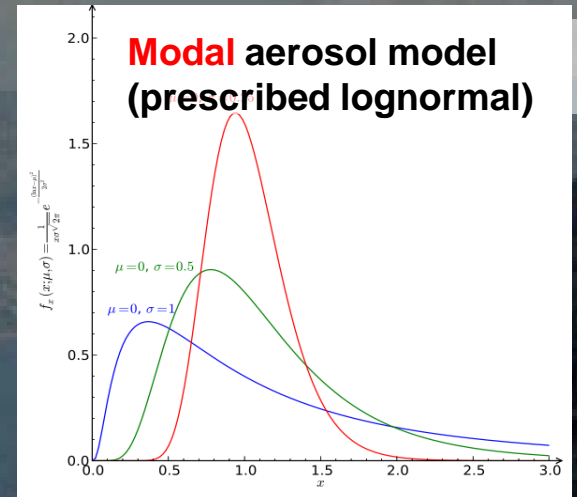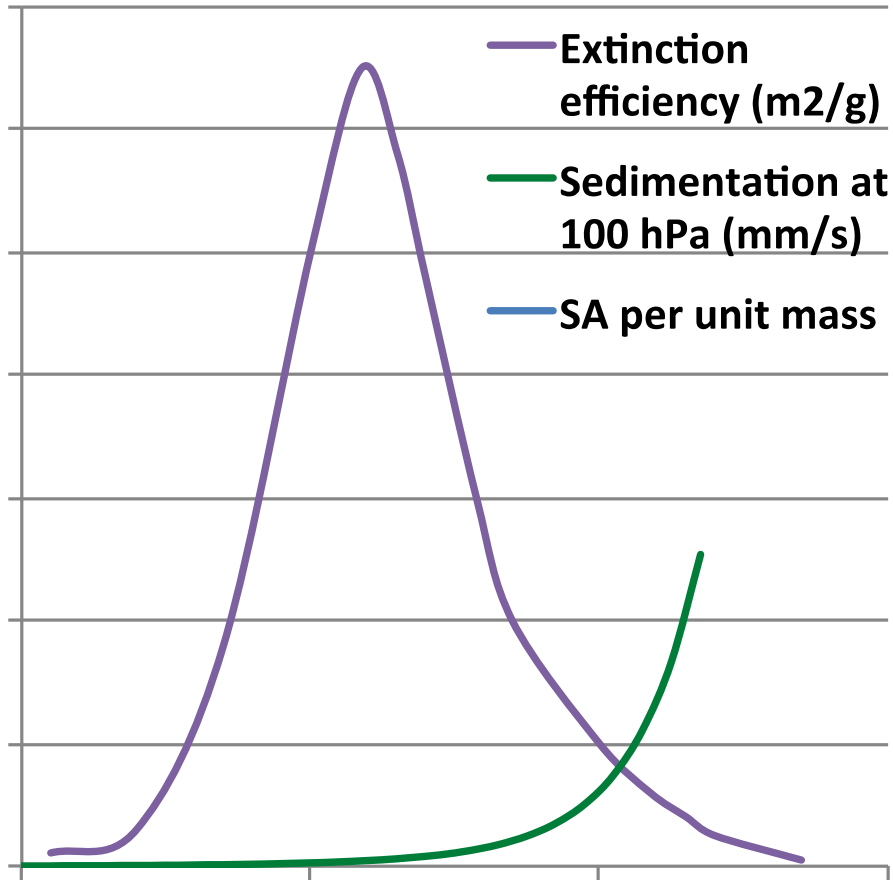# The importance of accurately representing aerosols from large volcanic eruptions

Jason M. English
LASP/University of Colorado

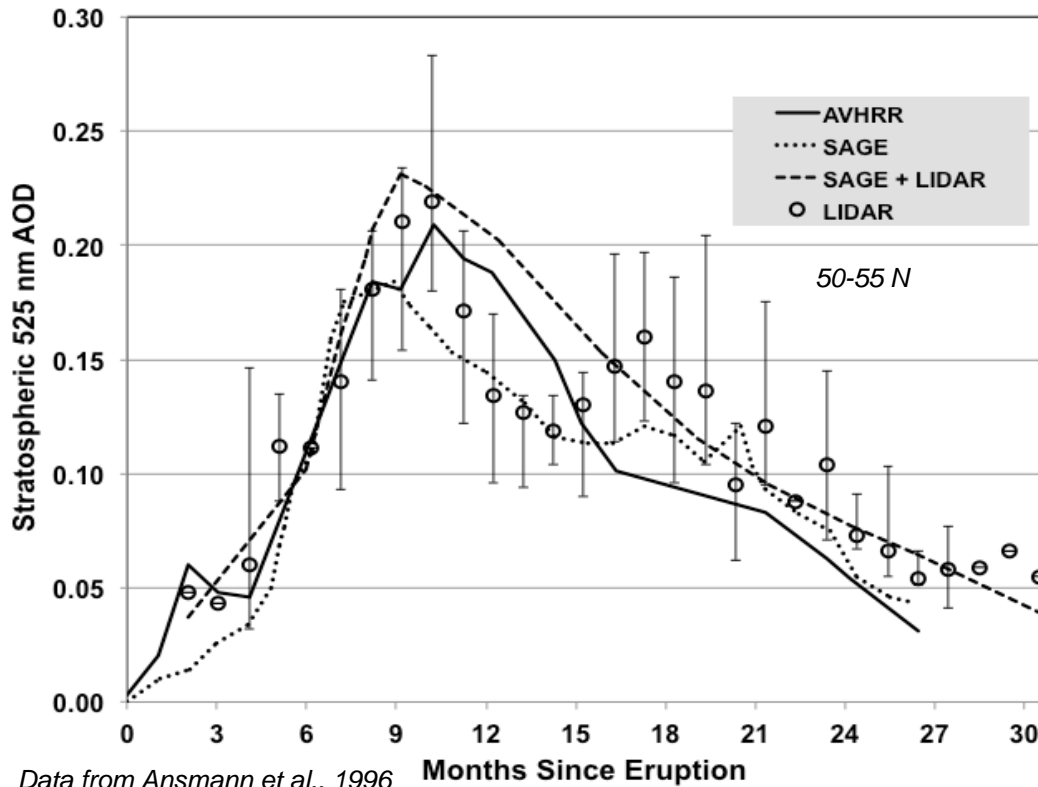**Thanks to collaborators**
Brian Toon and Michael Mills

Accurate representation of stratospheric aerosol is critical

- Extinction efficiency (m2/g)
- Sedimentation at 100 hPa (mm/s)
- SA per unit mass

Bulk aerosol model: predict mass, prescribes size.

Modal aerosol model (prescribed lognormal)

$$f_x(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$$

$\mu = 0, \sigma = 0.5$

$\mu = 0, \sigma = 1$

Sectional aerosol model (CARMA)
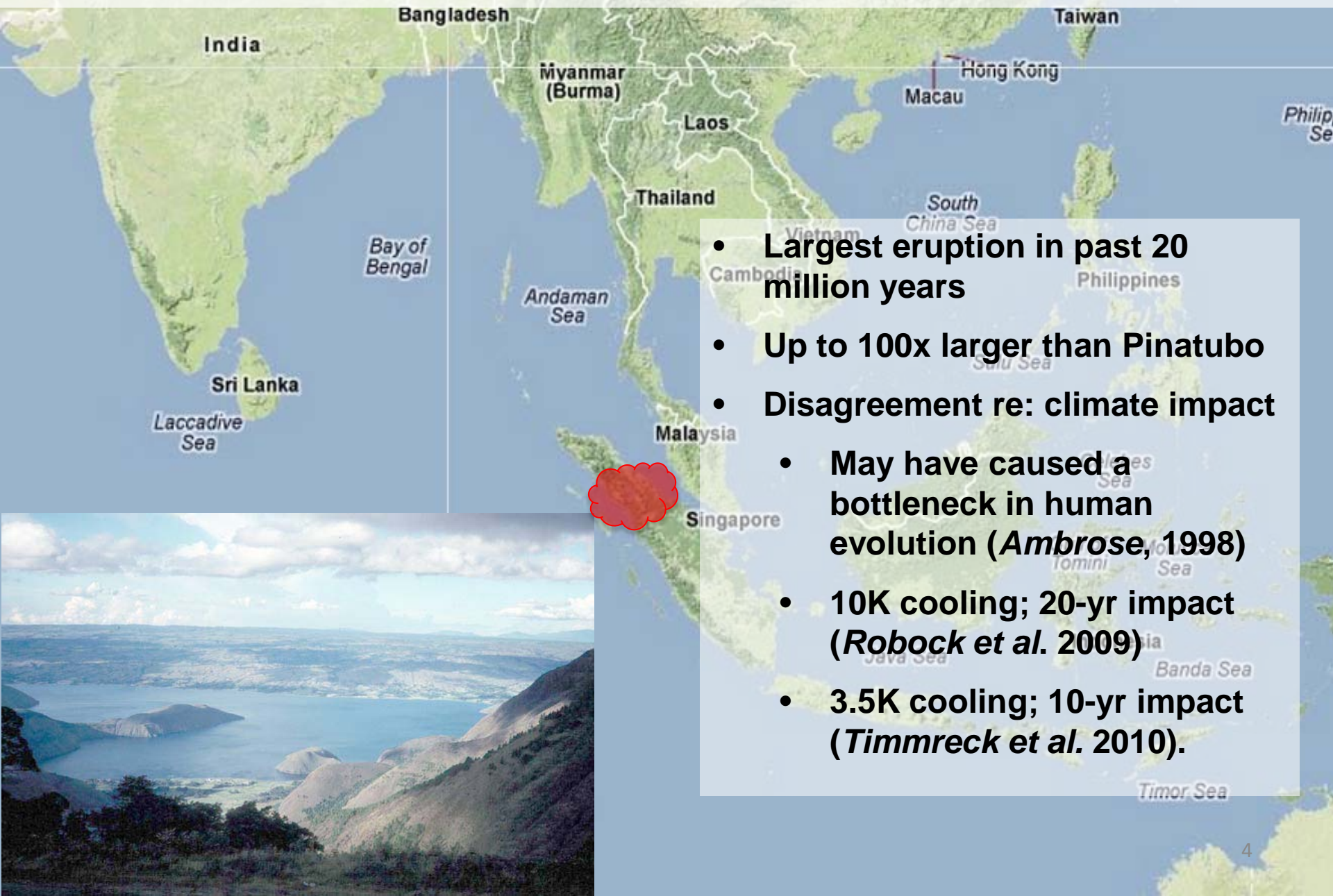
The 1991 eruption of Mt. Pinatubo

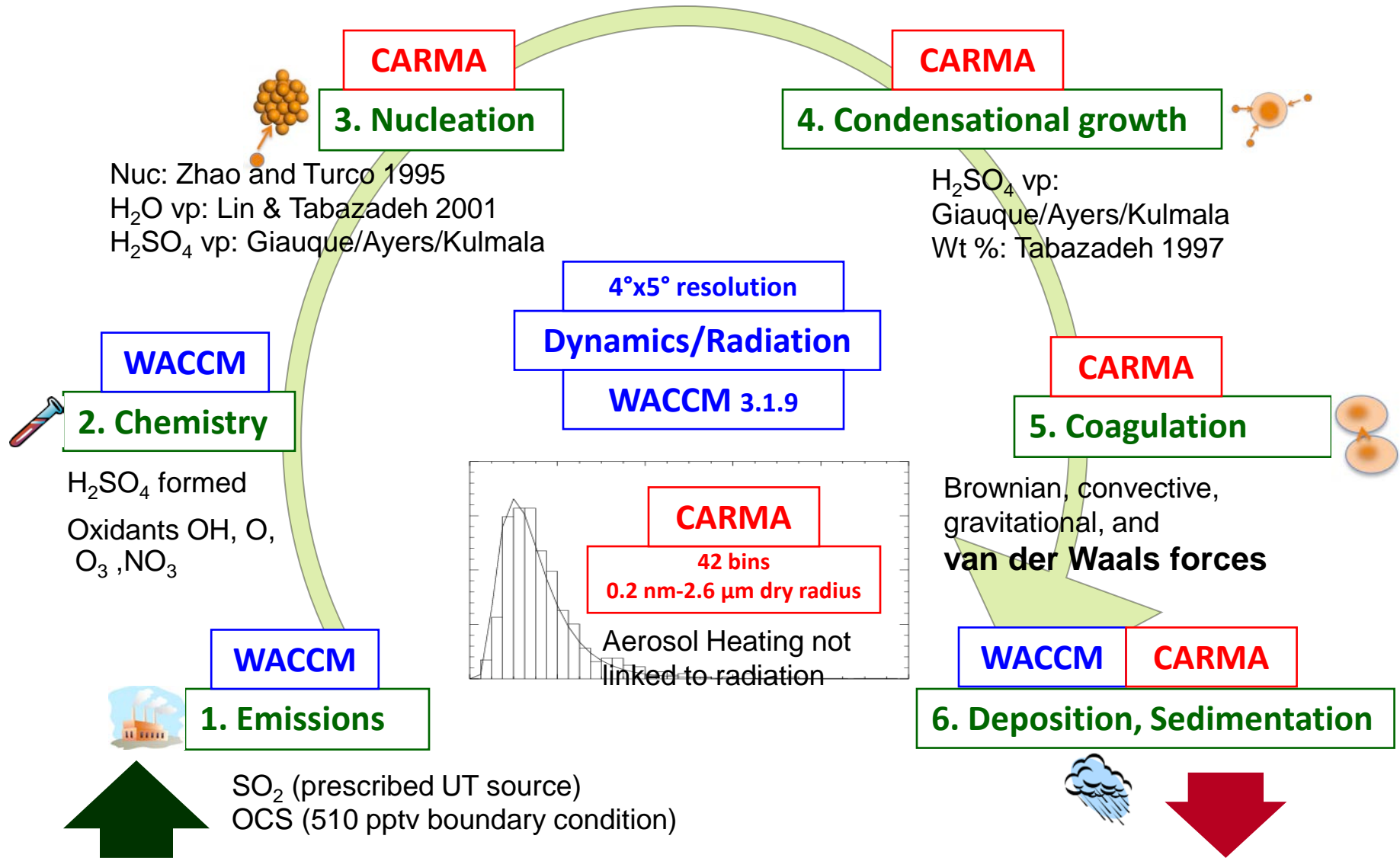*Data from Ansmann et al., 1996*

50-55 N
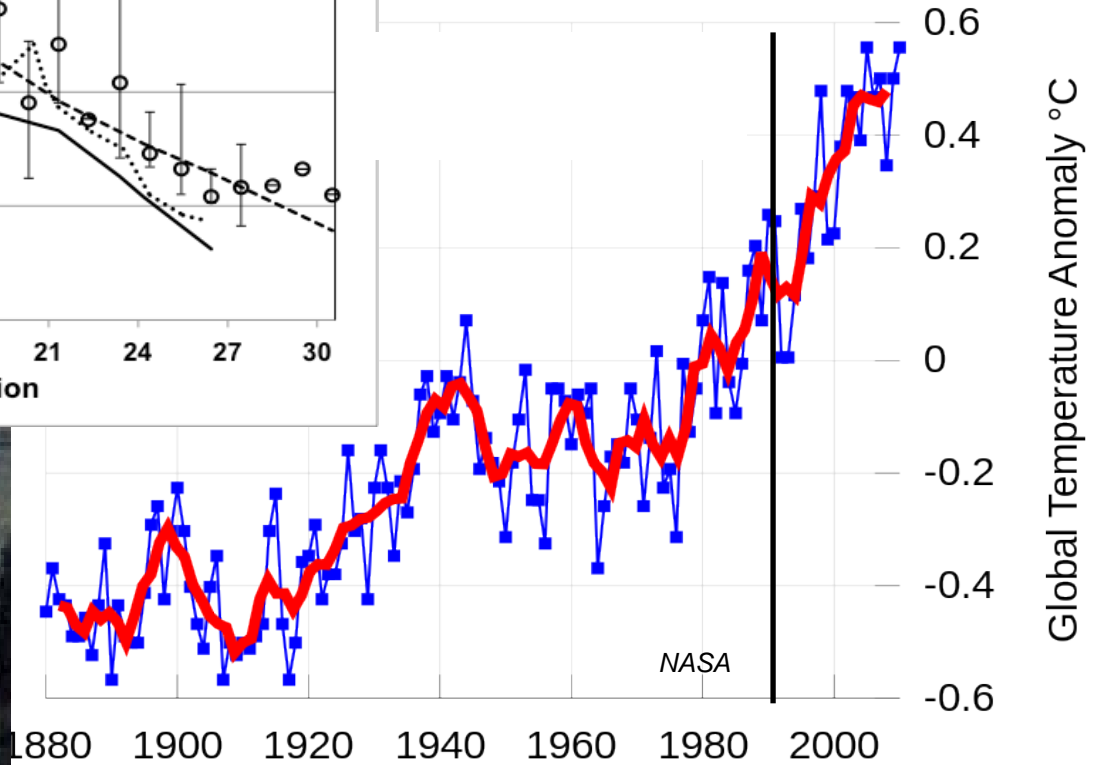
NASA

The Toba super-eruption 74,000 years ago

- **Largest eruption in past 20 million years**

- **Up to 100x larger than Pinatubo**

- **Disagreement re: climate impact**

  - **May have caused a bottleneck in human evolution (*Ambrose*, 1998)**

  - **10K cooling; 20-yr impact (*Robock et al.* 2009)**

 - **3.5K cooling; 10-yr impact (*Timmreck et al.* 2010).**

WACCM/CARMA Model

CARMA

3. Nucleation

Nuc: Zhao and Turco 1995
H_2O vp: Lin & Tabazadeh 2001
H_2SO_4 vp: Giauque/Ayers/Kulmala

CARMA

4. Condensational growth

H_2SO_4 vp:
Giauque/Ayers/Kulmala
Wt %: Tabazadeh 1997

4°x5° resolution

Dynamics/Radiation

WACCM 3.1.9

WACCM

2. Chemistry

H_2SO_4 formed

Oxidants OH, O,
O_3 ,NO_3

CARMA

5. Coagulation

Brownian, convective,
gravitational, and
van der Waals forces

CARMA

**42 bins
0.2 nm-2.6 μm dry radius**

Aerosol Heating not
linked to radiation

WACCM

1. Emissions

SO_2 (prescribed UT source)
OCS (510 pptv boundary condition)

WACCM **CARMA**

6. Deposition, Sedimentation

English et al., 2011, ACP

Three eruptions; with and without van der Waals

| Three eruptions simulated	
Pinatubo	10 Tg S
Pinatubo x 10	100 Tg S
Toba	1000 Tg S

Simulated SO$_2$ cloud 2°S – 14°N 95 – 115°E

- **10-year simulations**
- **SO$_2$ gas injected continuously over 48 hours on June 14-15 of first year**
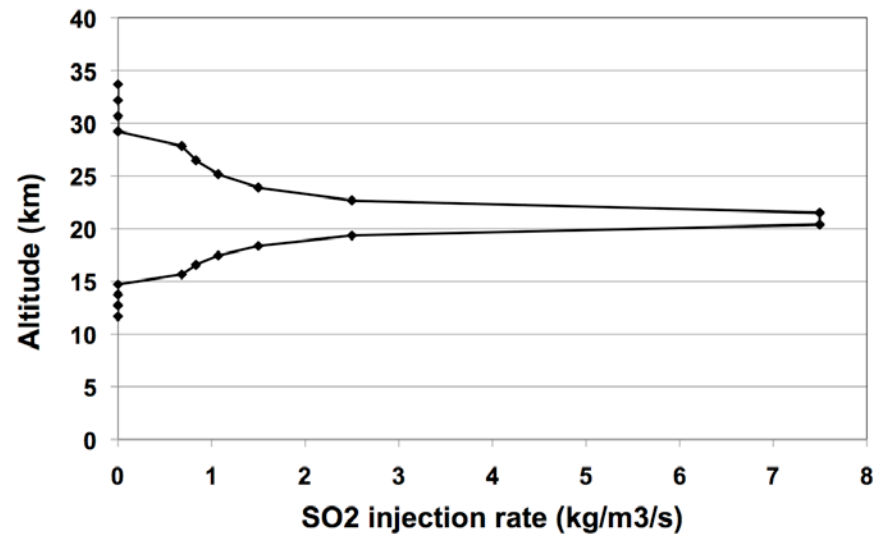
Pinatubo: Model captures peak but declines too quickly

Data from Russell et al., 1996
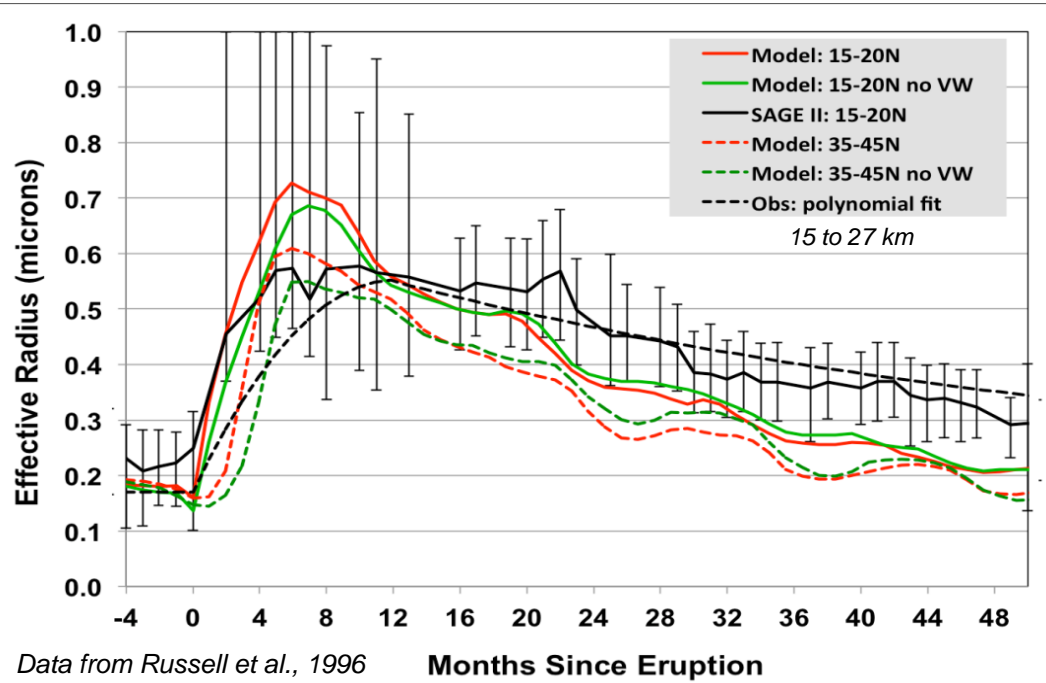
- **Model is mostly within error bars but declines too quickly (need aerosol heating, QBO)**

- **Including van der Waals forces increases effective radius and reduces AOD**
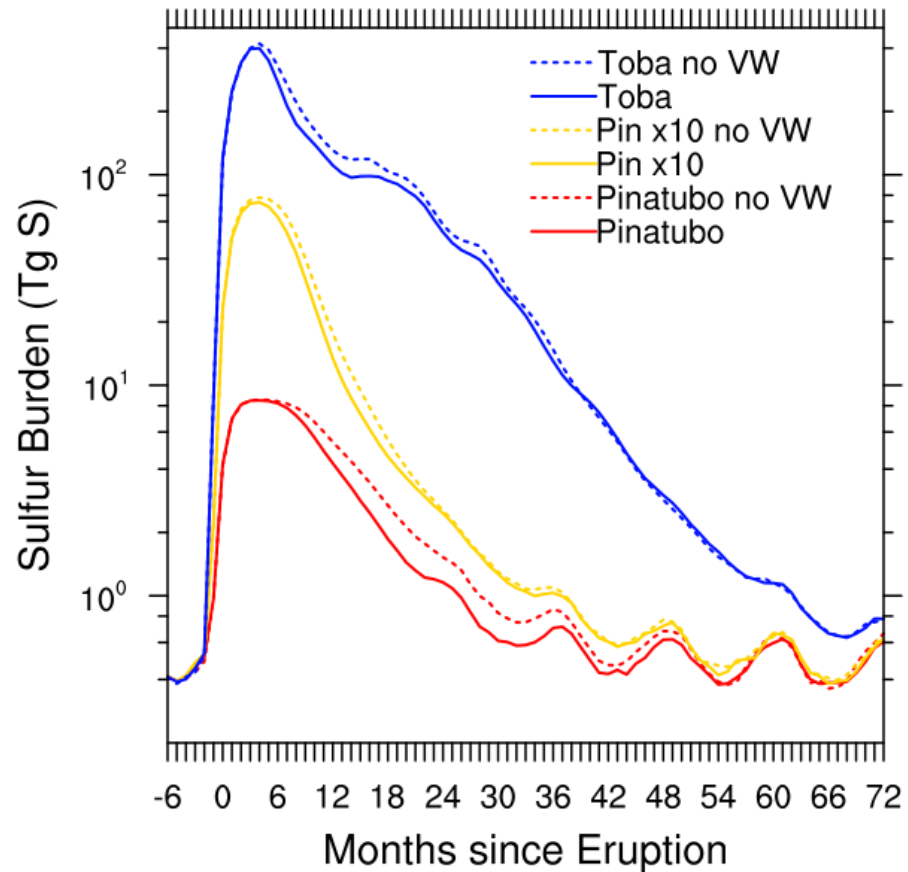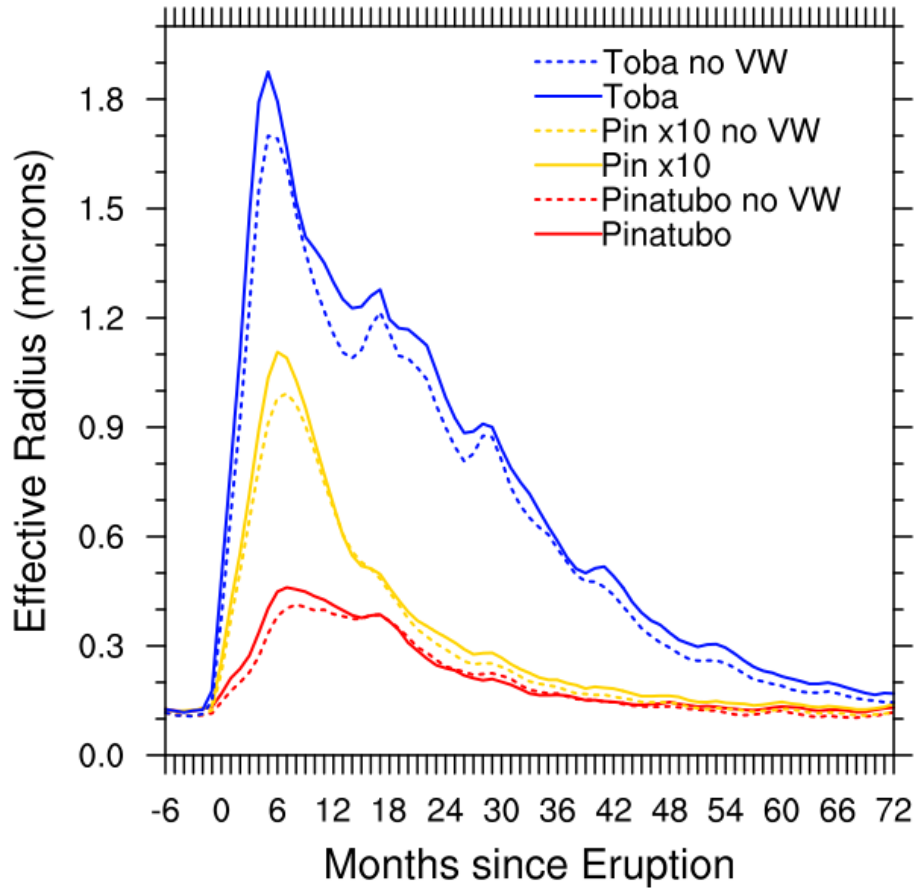

Data from Ansmann et al., 1996
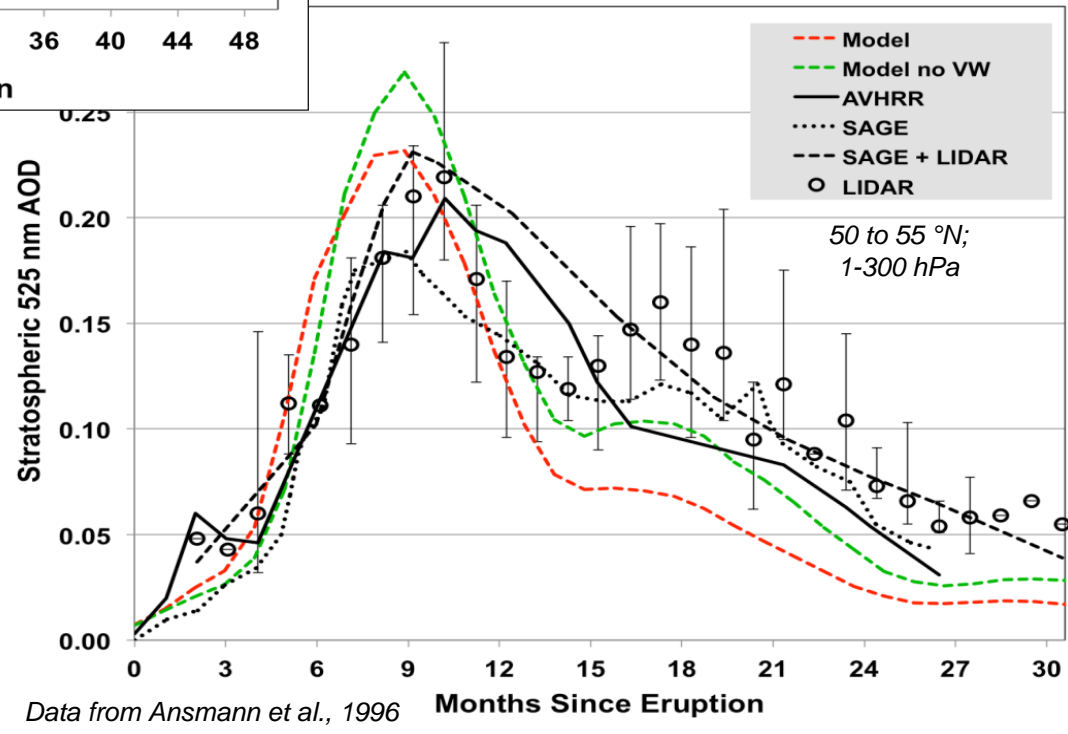
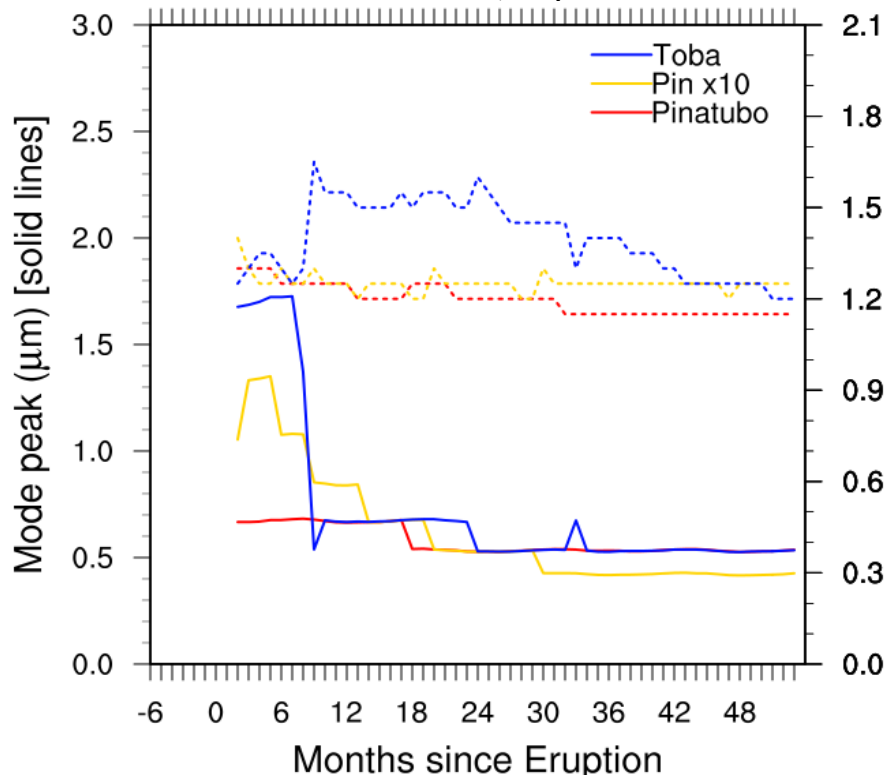# AOD is limited in larger eruptions, esp. when van der Waals forces are included (100x emissions = 20x AOD). Why?
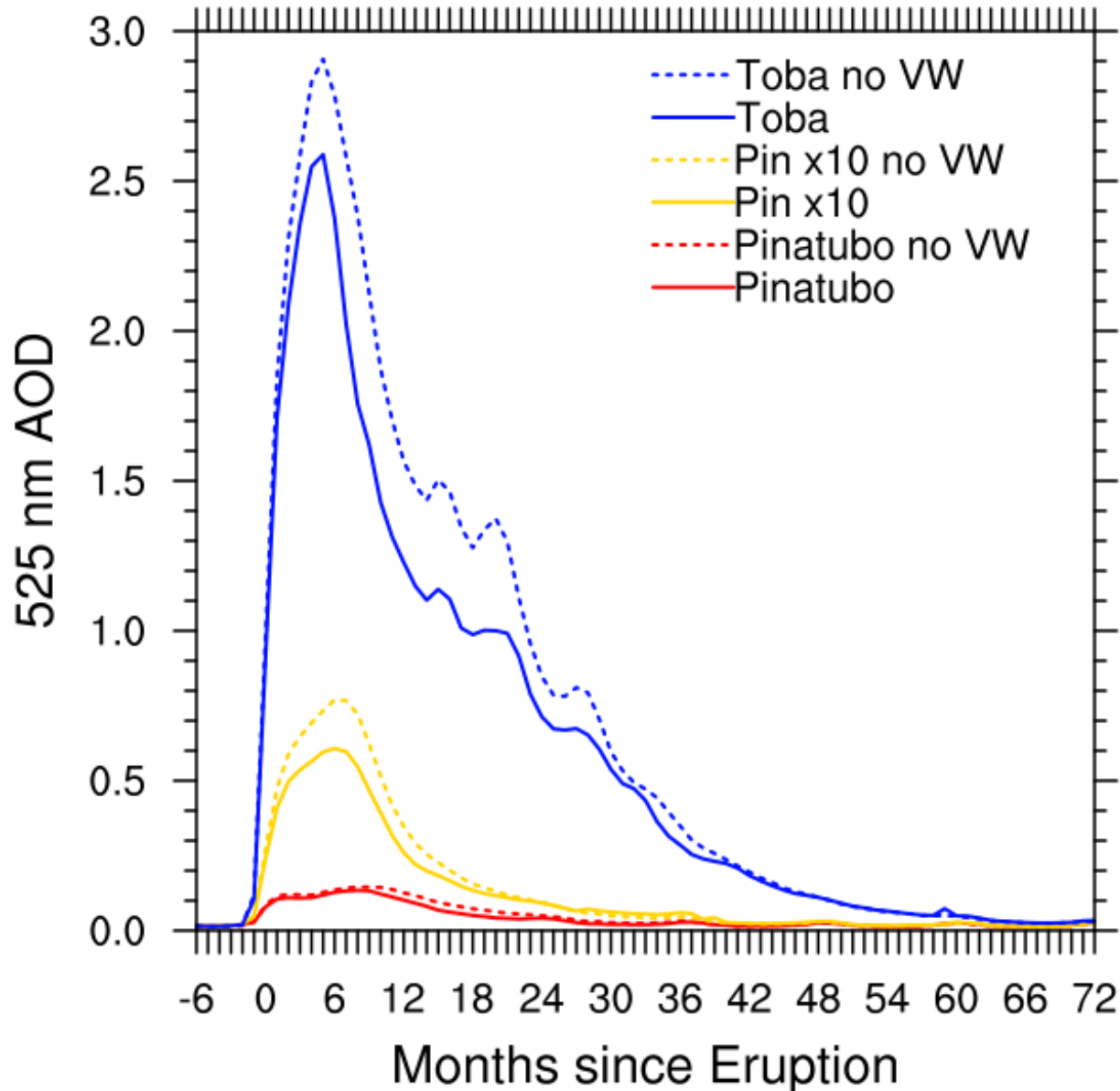
Larger Eruptions have larger particles, limited burdens
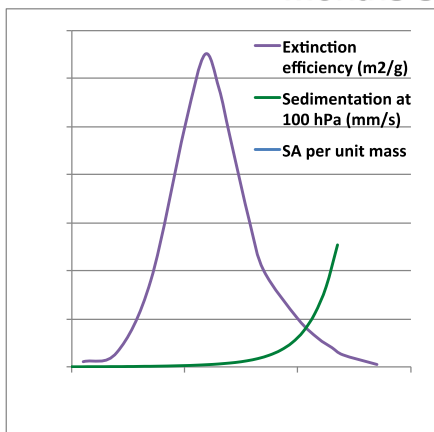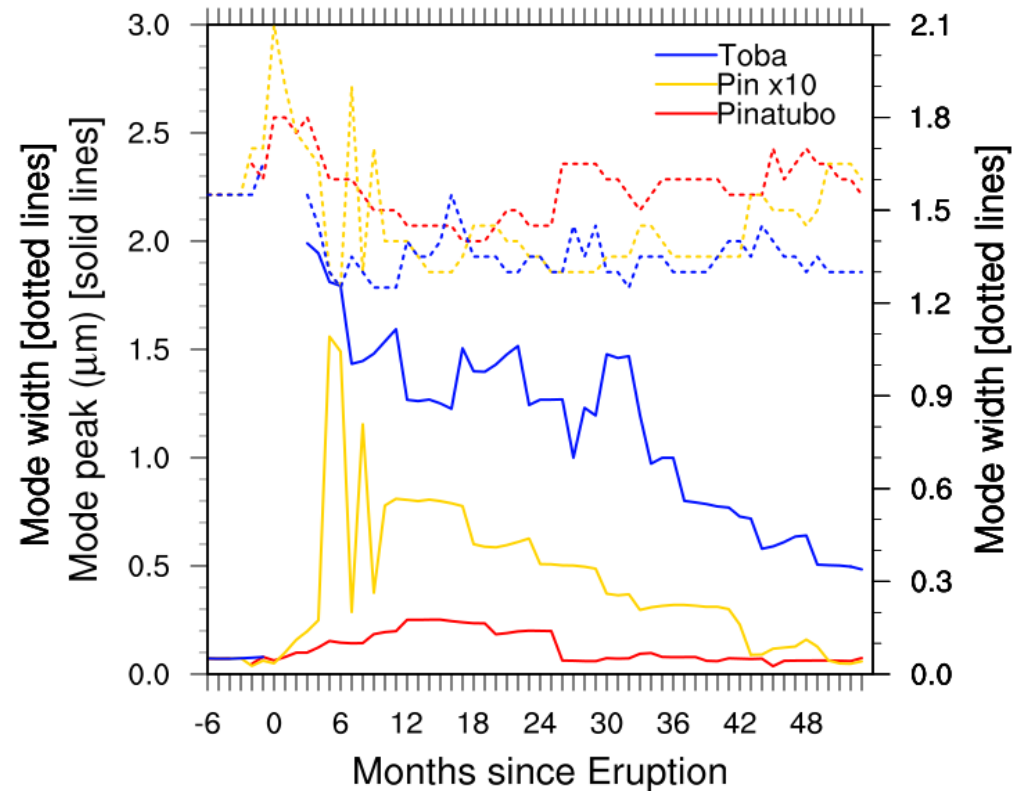## Van der Waals forces increases R_{eff}

Mode peak size and widths evolve

20-200 hPa; Equator

50-990 hPa; 80-90°S

Comparing Toba Studies	R_eff	Mode width
Robock et al., 2009 (Bulk)	~0.6 µm (0.45 dry)	1.25
Timmreck et al., 2010 (Modal)	0.8 – 1.1 µm	1.2
English et al., 2013 (Sectional)	1.1 – 2.2 µm	1.2 - 2.1

Summary/Next Steps

- **Large eruptions have self-limiting radiative effects due to increased particle size***

  - Toba (**100x** Pinatubo) has only **50x** burden; **20x** AOD; 5-yr AOD
  - Particle size grows to 2.0 µm! (Van der Waals increases size by 25%)
  - Mode widths vary from 1.2 to 2.1; modal models don't allow this to evolve (larger widths mean shorter lifetime)

- **Accurate representation of stratospheric aerosol processes is critically important to constrain:**

  - Devastation from super-eruptions
  - Effects of small/moderate volcanoes on recent temperature trends
  - Geoengineering schemes

- **Two paths for stratospheric aerosol model development**

  - WACCM5/CARMA for most accurate representation
  - WACCM5 & CAM5 with modified MAM (Mike Mills, Ryan Neely, Simone Tilmes)

* English, J. M., O. B. Toon, and M. J. Mills (2013), Microphysical simulations of large volcanic eruptions: Pinatubo and Toba, JGR.