



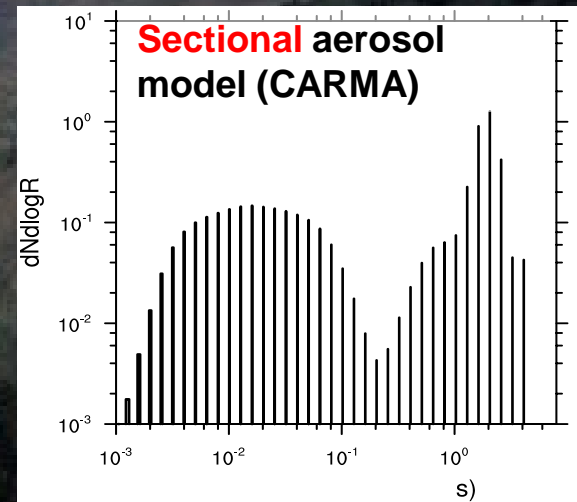
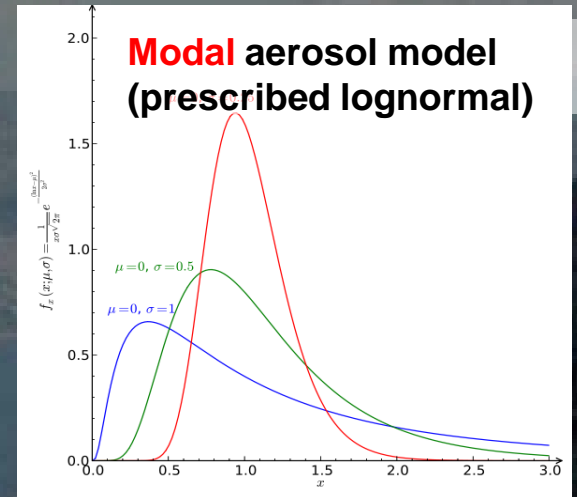
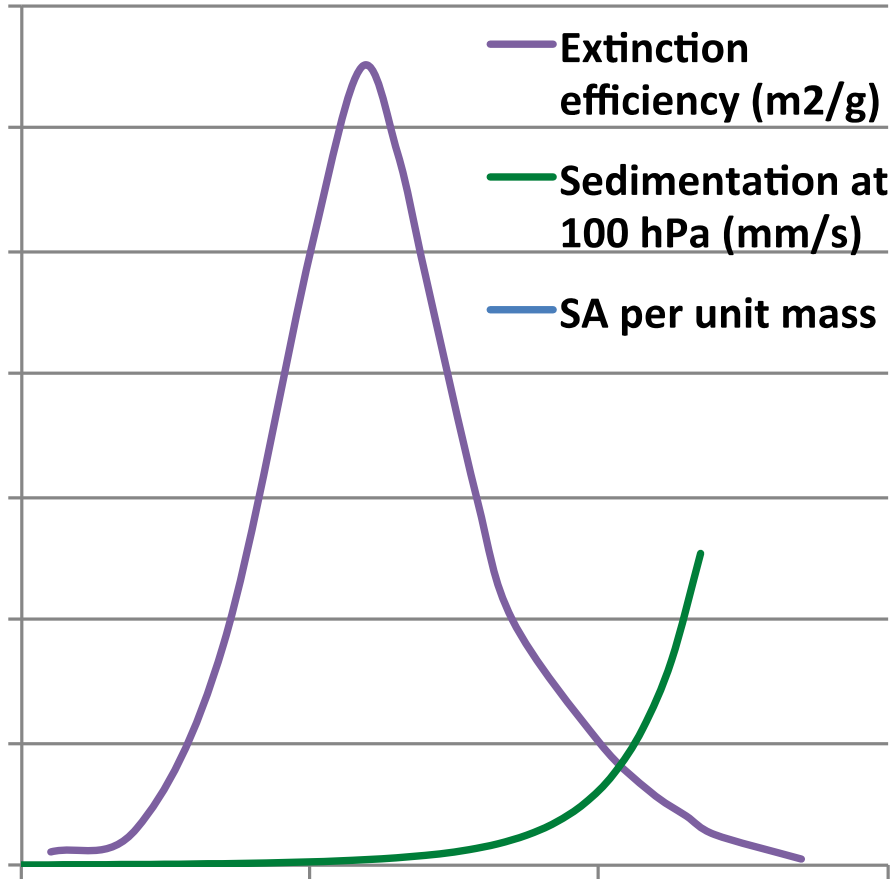
Surprising particle growth after large volcanic eruptions

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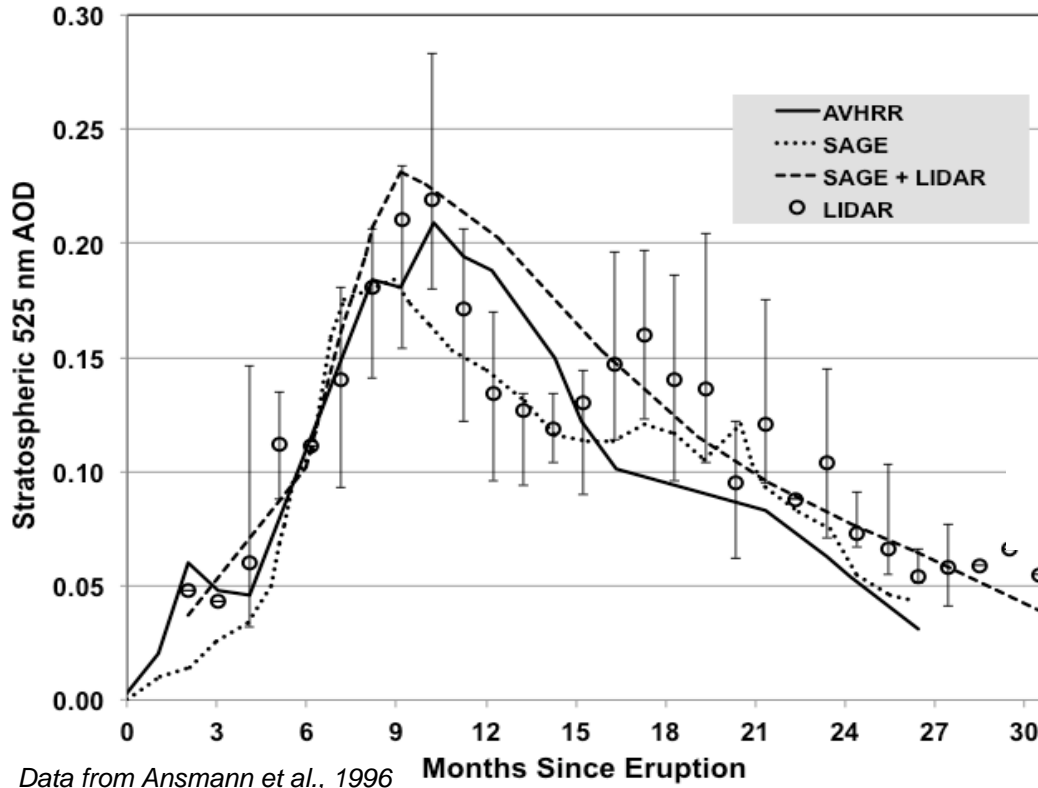
Thanks to collaborators
Brian Toon and Michael Mills

Accurate representation of stratospheric aerosol is critical

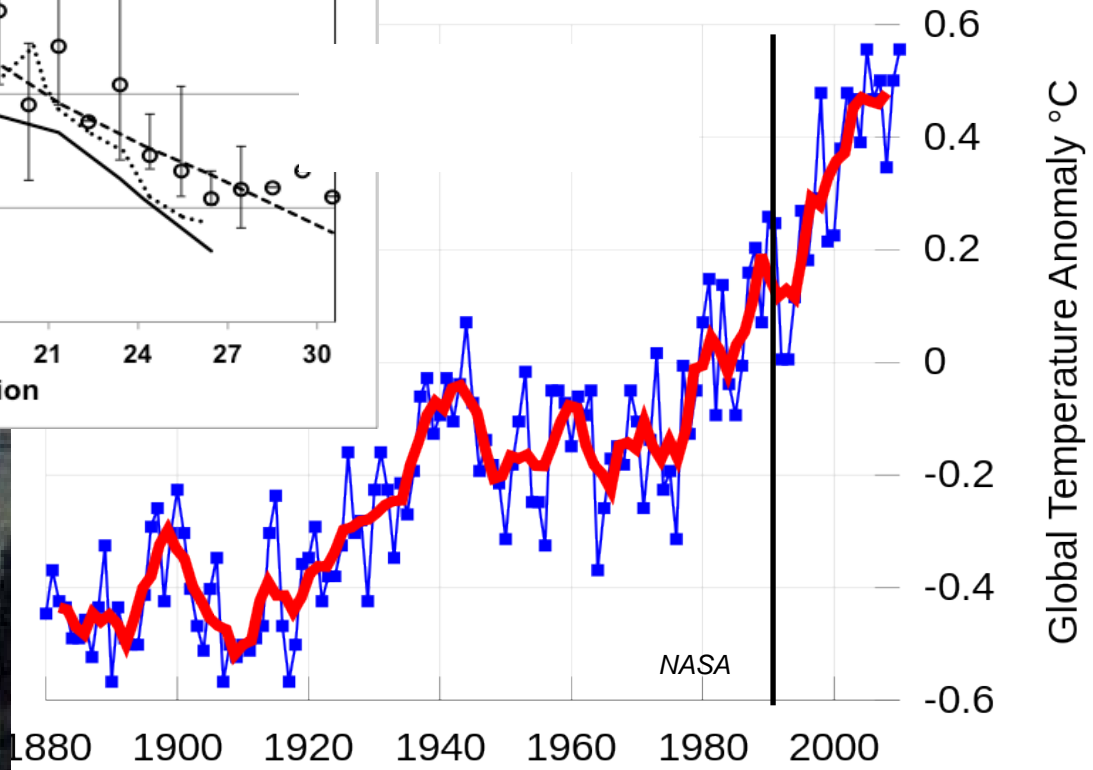
Bulk aerosol model:
predict mass,
prescribes size.



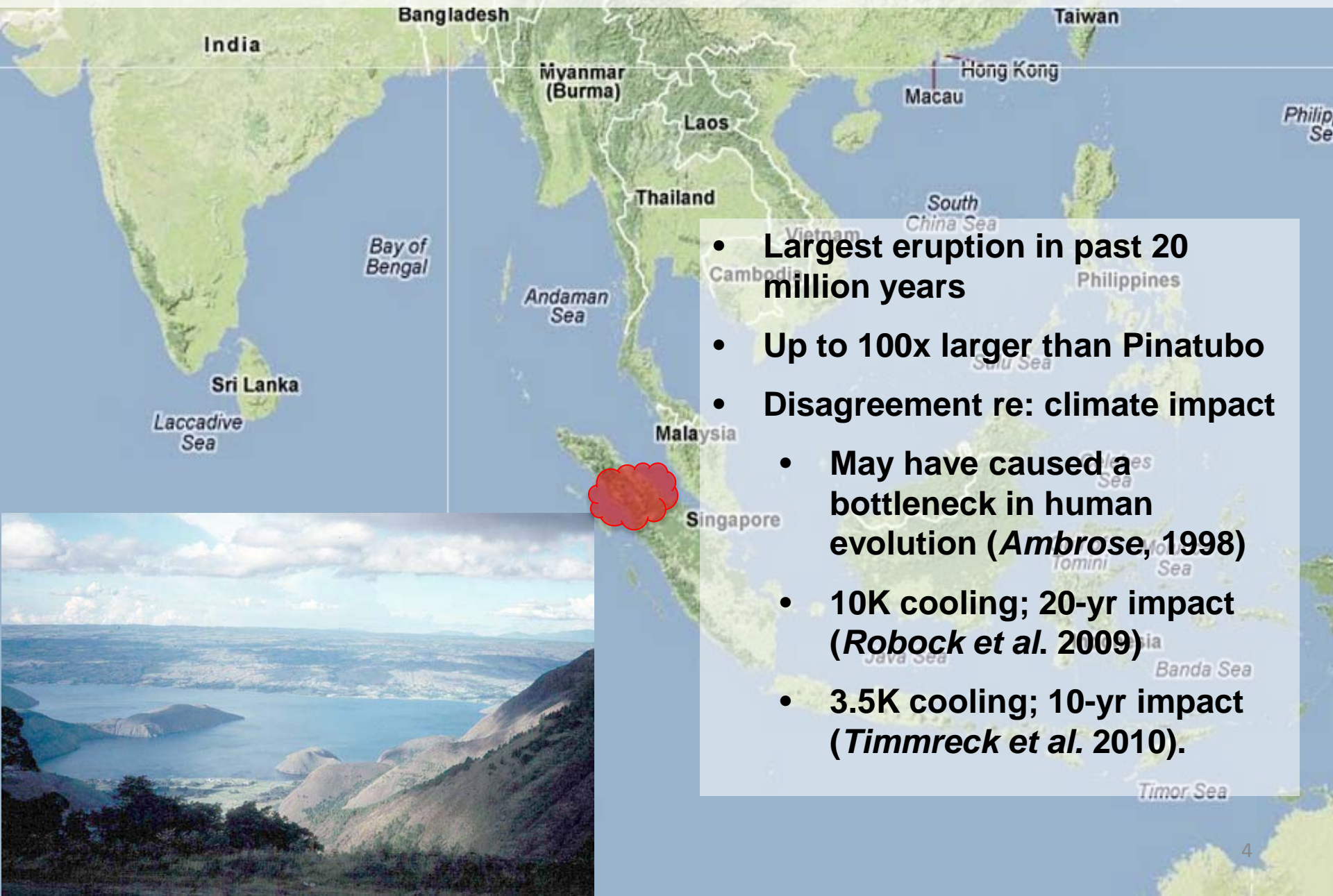
The 1991 eruption of Mt. Pinatubo



Data from Ansmann et al., 1996

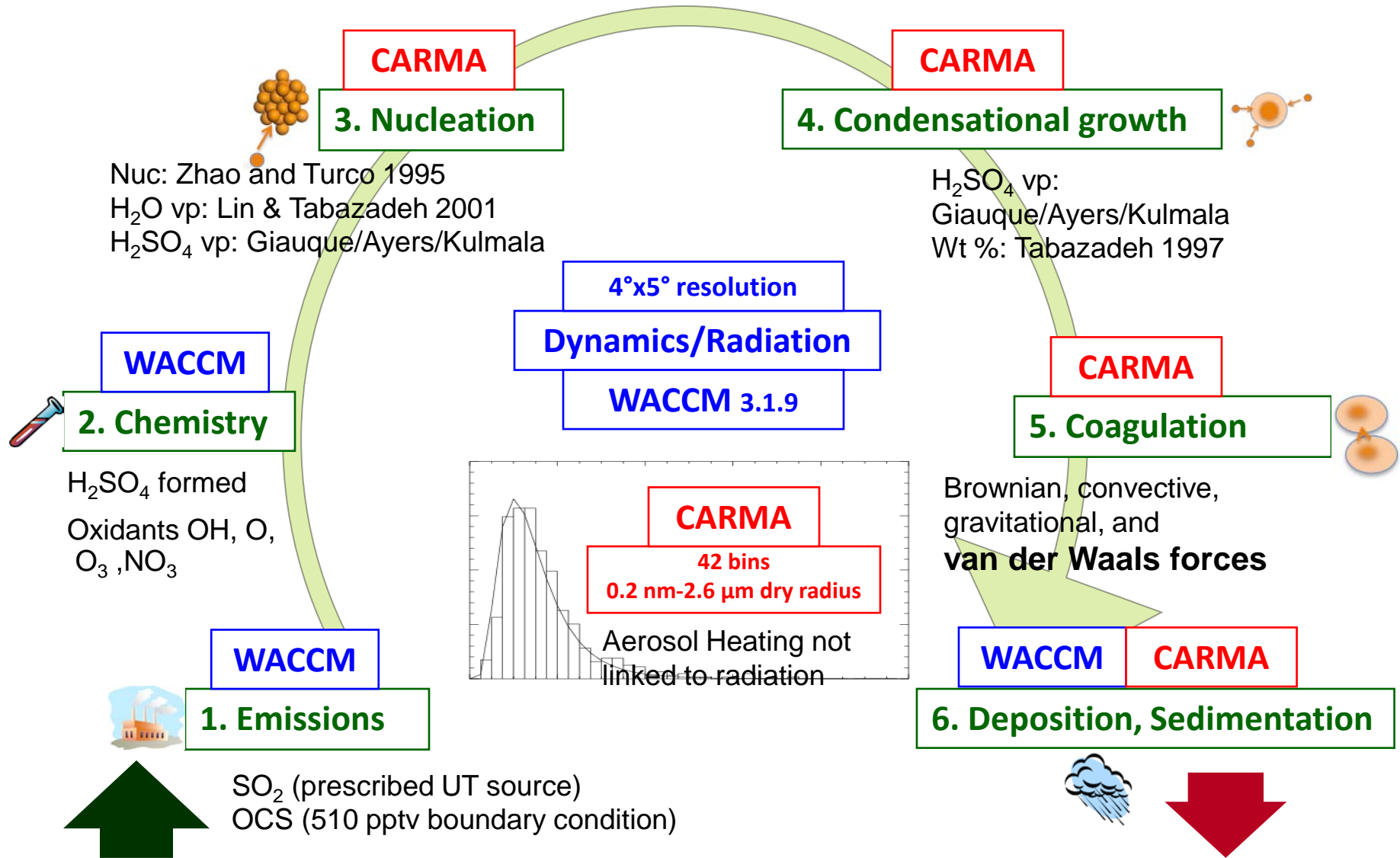


The Toba super-eruption 74,000 years ago



- 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



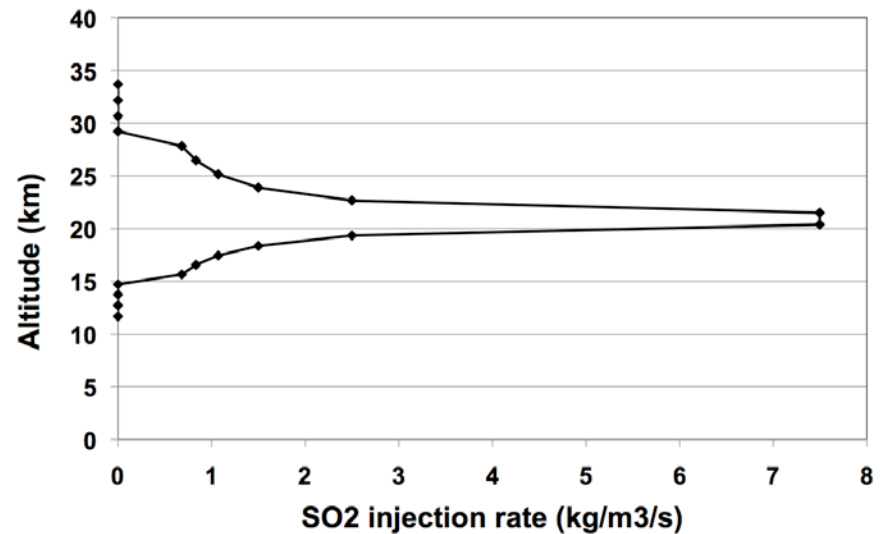
Three eruptions; with and without van der Waals

Three eruptions simulated

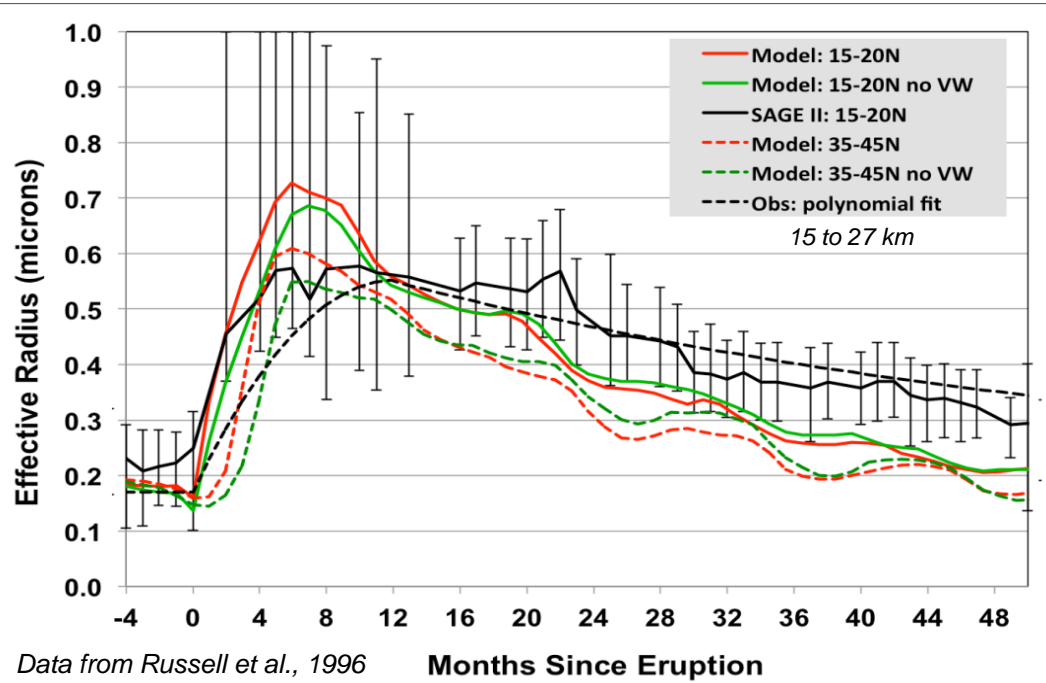
Pinatubo	10 Tg S
Pinatubo x 10	100 Tg S
Toba	1000 Tg S



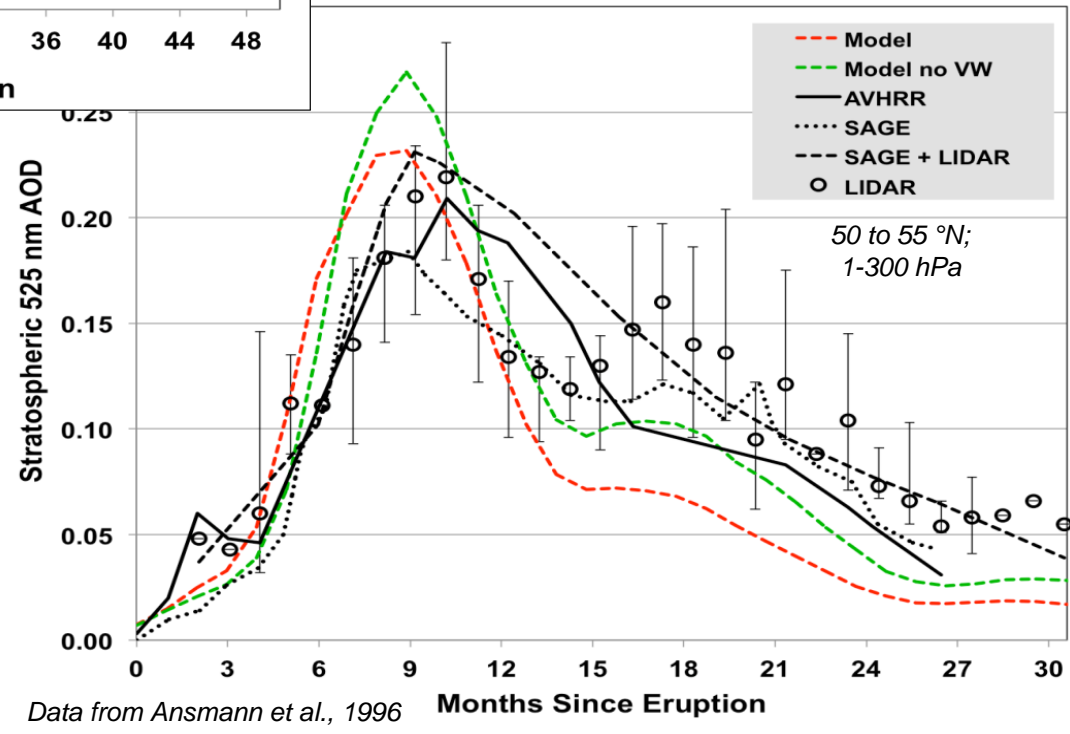
- 10-year simulations
- SO_2 gas injected continuously over 48 hours on June 14-15 of first year



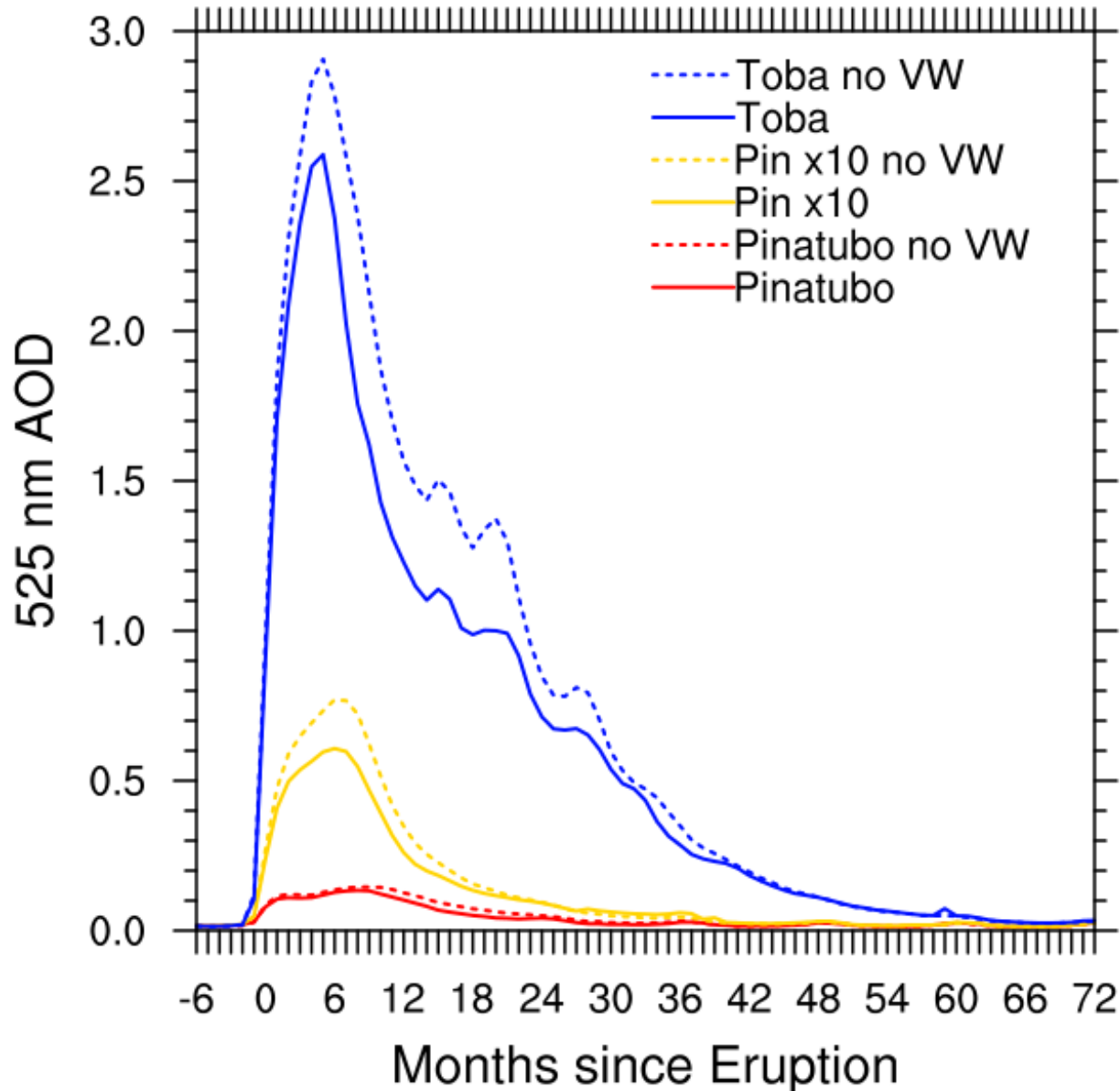
Pinatubo: Model captures peak but declines too quickly



- 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

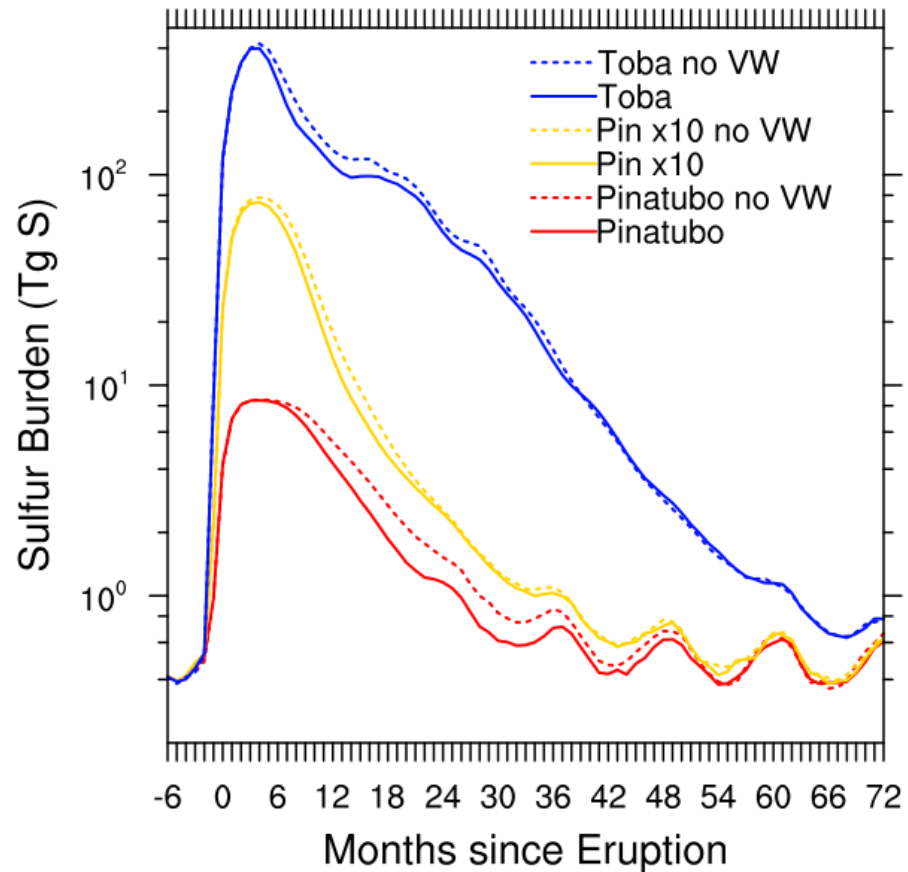
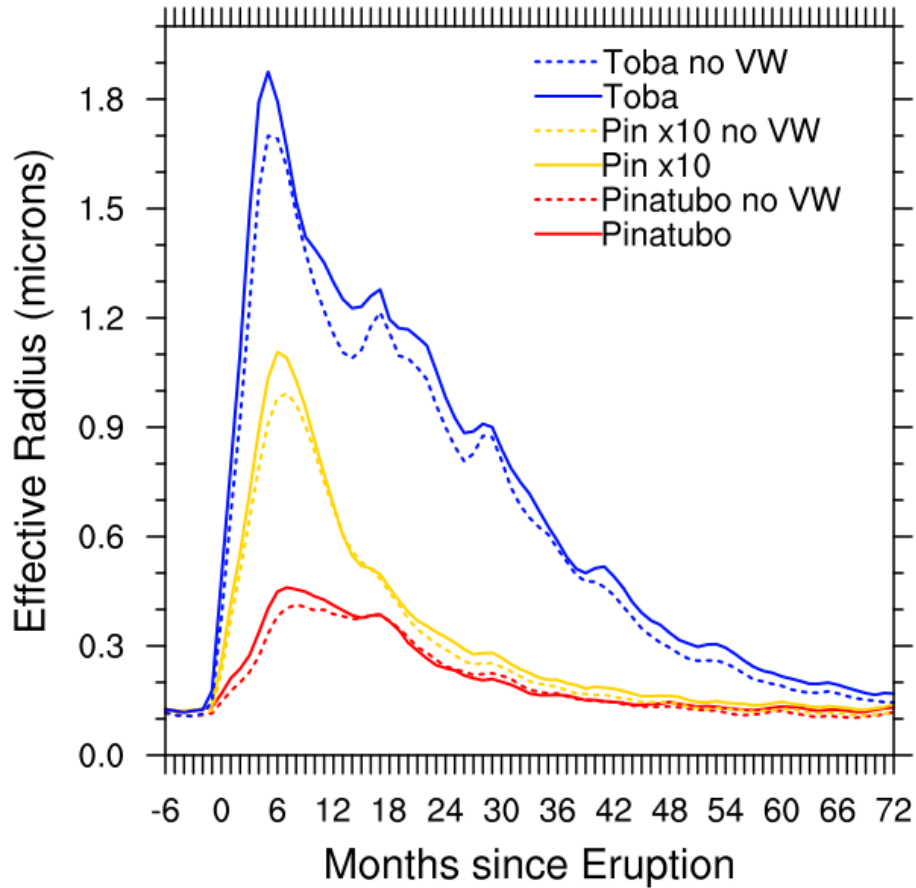


AOD is limited in larger eruptions, esp. when van der Waals forces are included (100x emissions = 20x AOD). Why?



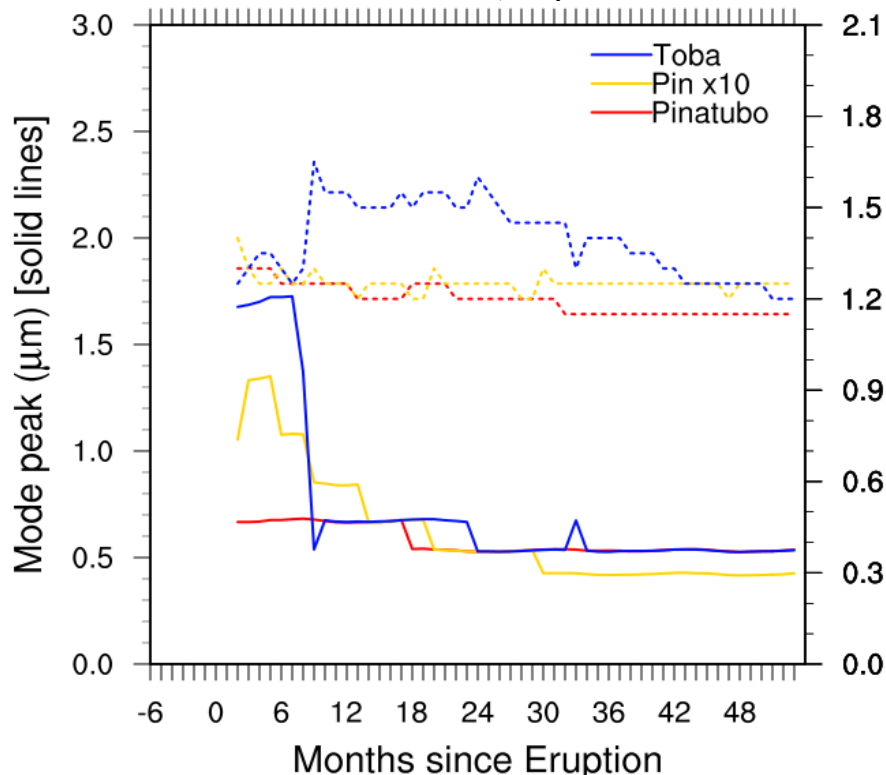
Larger Eruptions have larger particles, limited burdens

Van der Waals forces increases R_{eff}

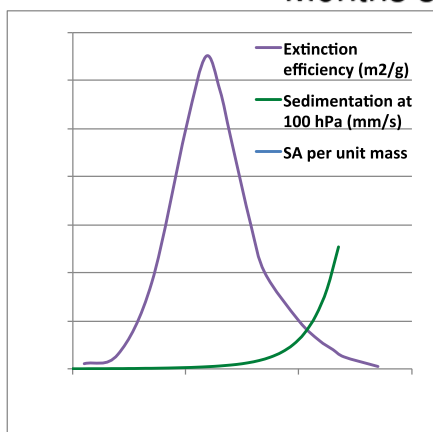
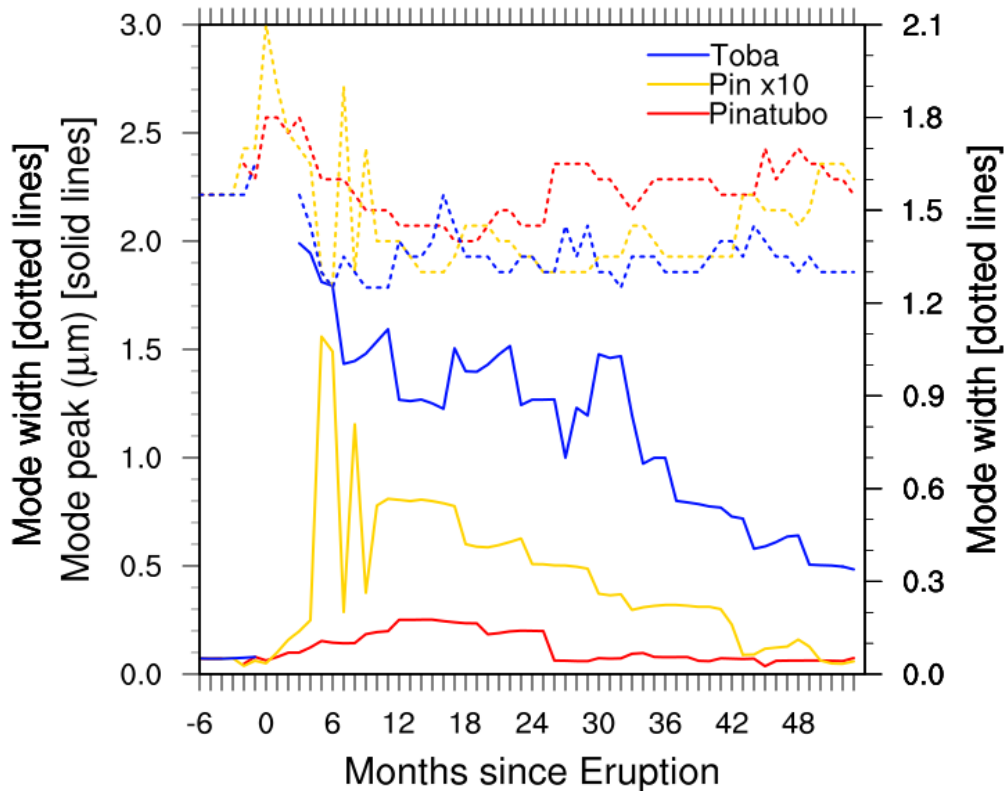


Mode peak size and widths evolve

20-200 hPa; Equator



50-990 hPa; 80-90°S



Comparing Toba Studies	R_{eff}	Mode width
<i>Robock et al., 2009</i> (Bulk)	$\sim 0.6 \mu\text{m}$ (0.45 dry)	1.25
<i>Timmreck et al., 2010</i> (Modal)	0.8 – 1.1 μm	1.2
<i>English et al., 2013</i> (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.