Microphysical simulations of large volcanic eruptions: Pinatubo and Toba

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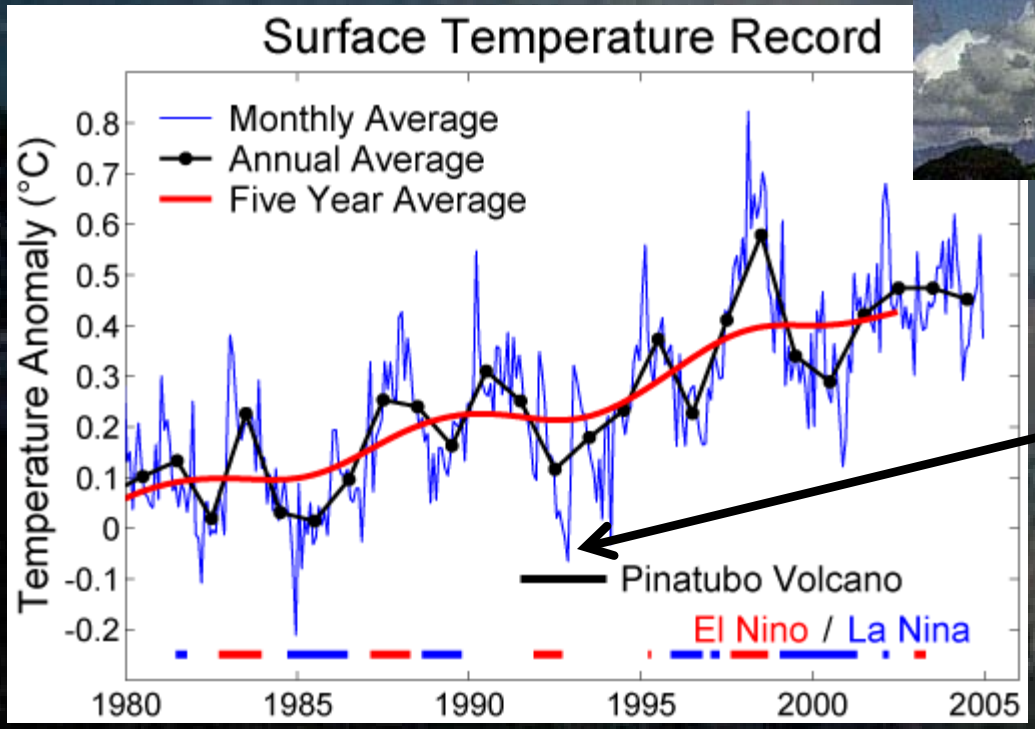
Thanks to collaborators
Brian Toon and Michael Mills

The 1991 eruption of Mt. Pinatubo

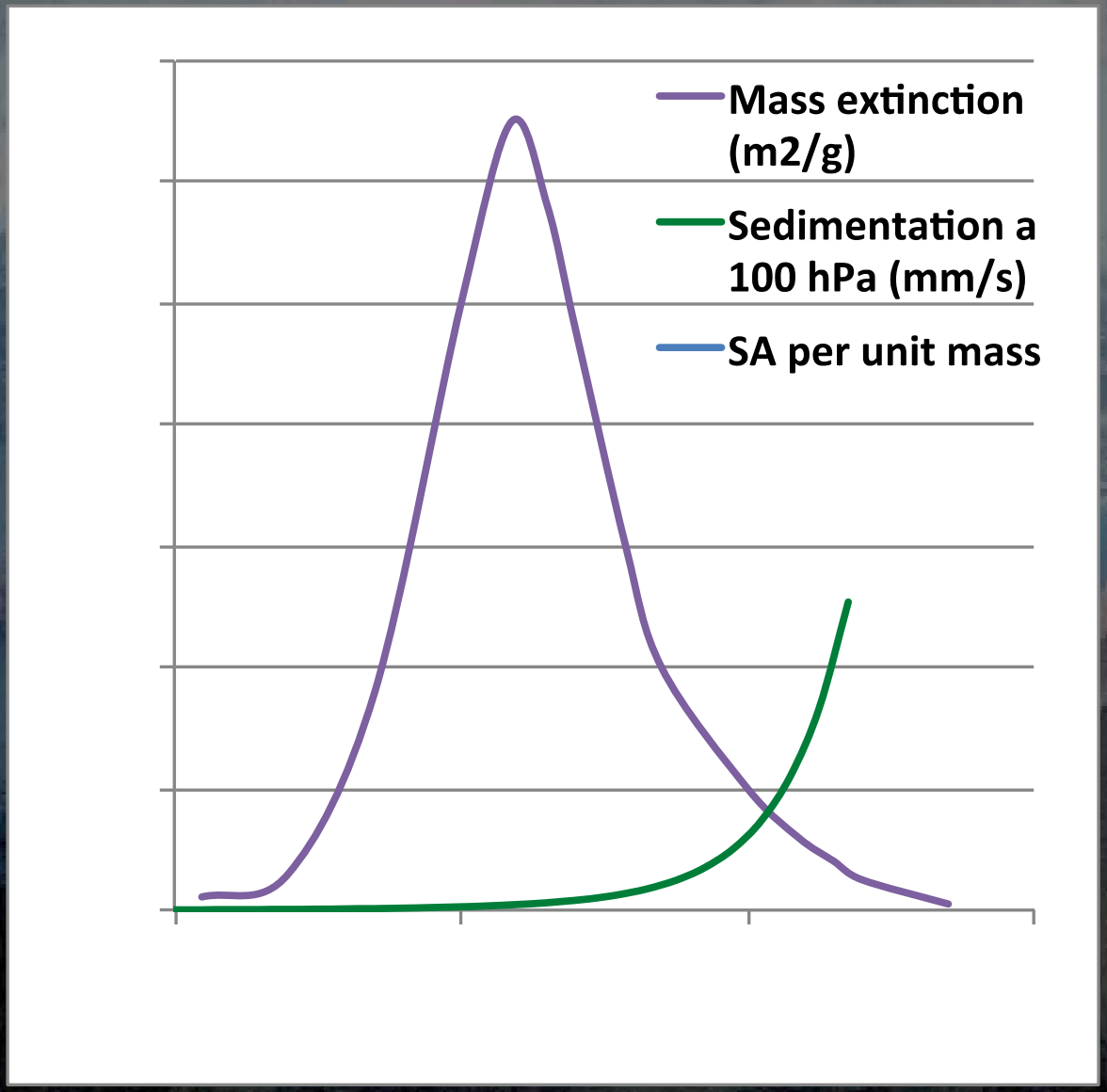


- 1992: Temperature dropped 0.5°C; coolest year in the past 25 years
- We also saw ozone loss, hydrological changes

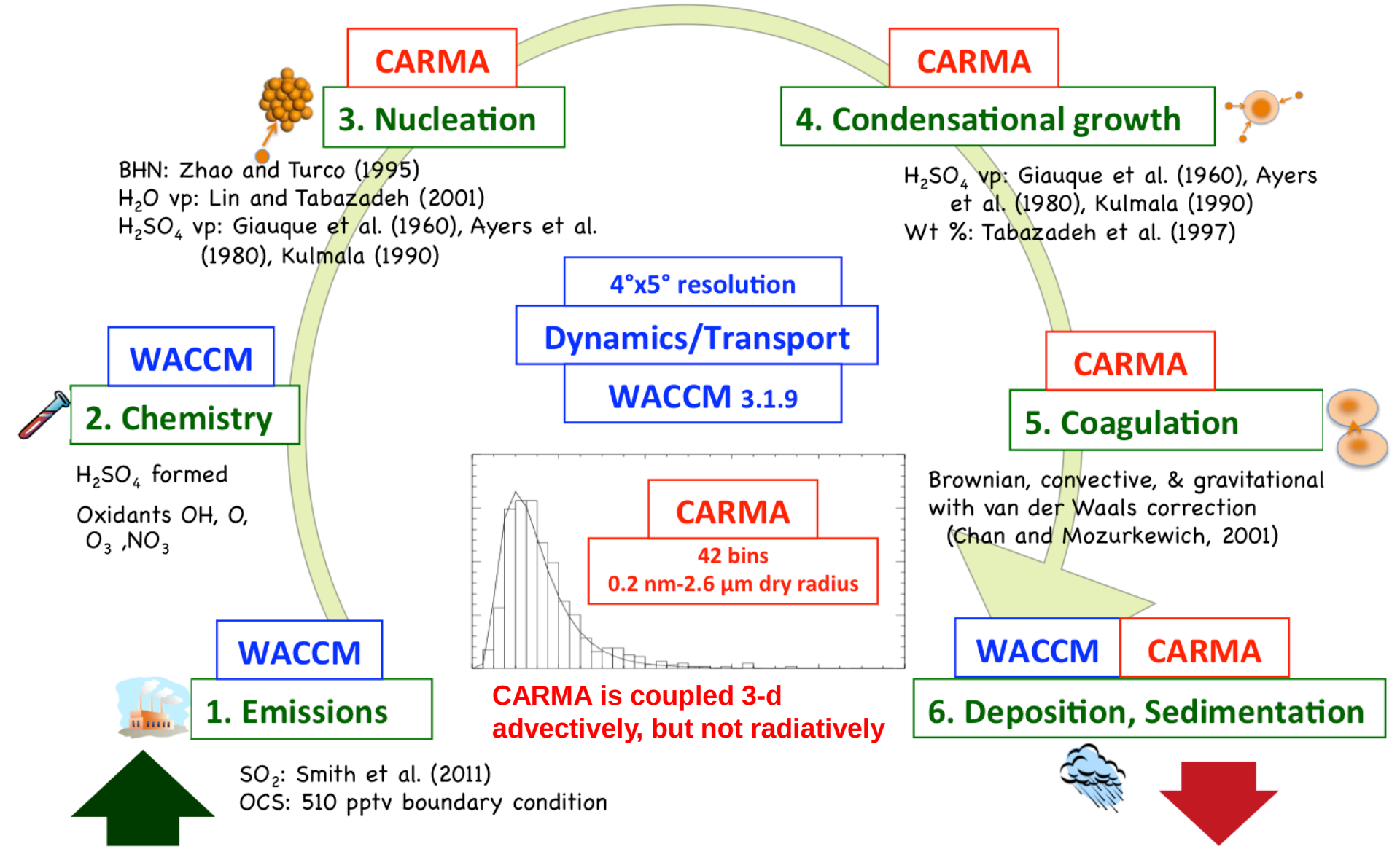
The Toba super-eruption 74,000 years ago

- Largest eruption in past 20 million years
- Up to 100x larger than Pinatubo
- Global T dropped 3-5°C
- Cooling lasted 2-20 years
- May have caused a bottleneck in human evolution

The importance of getting aerosol size right



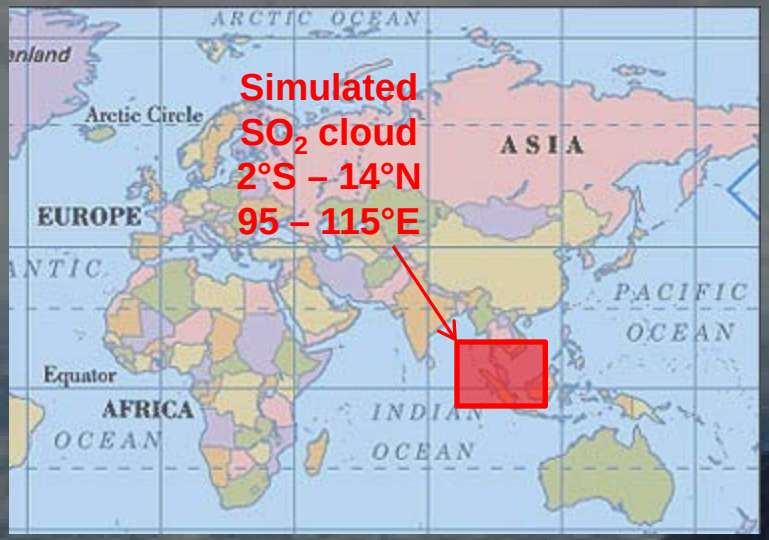
WACCM/CARMA model

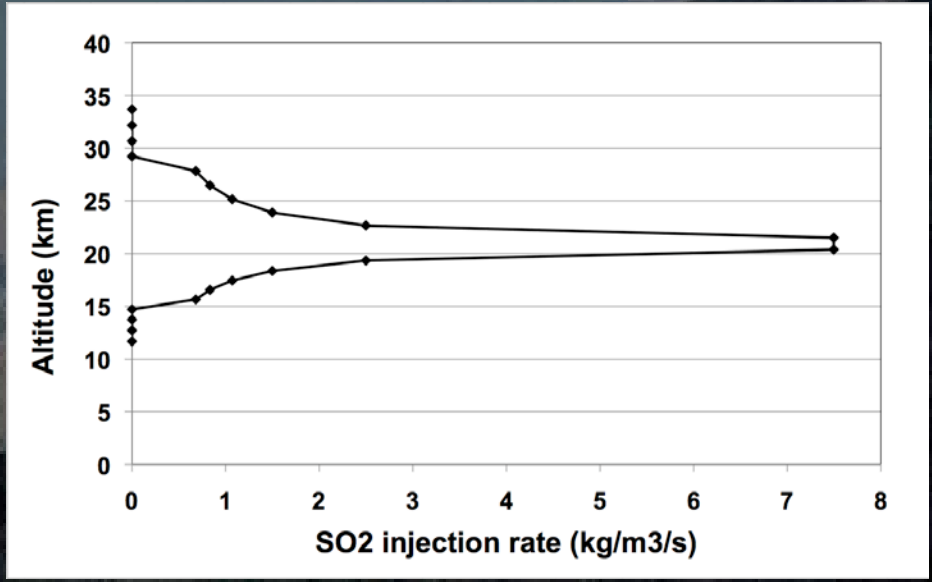


Experimental Design

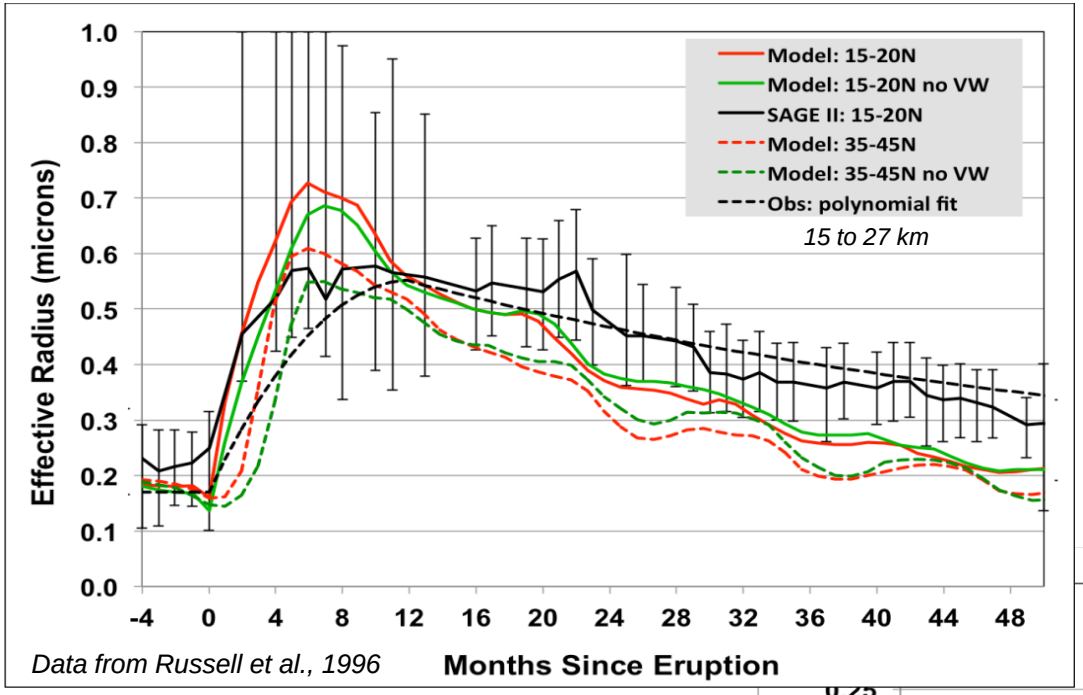
Three eruptions simulated	
Pinatubo	10 Tg S
Pinatubo x 10	100 Tg S
Toba	1000 Tg S

- Simulations with and without van der Waals forces (no VW)
- 10-year simulations
- SO_2 gas injected continuously over 48 hours on June 14-15 of first year

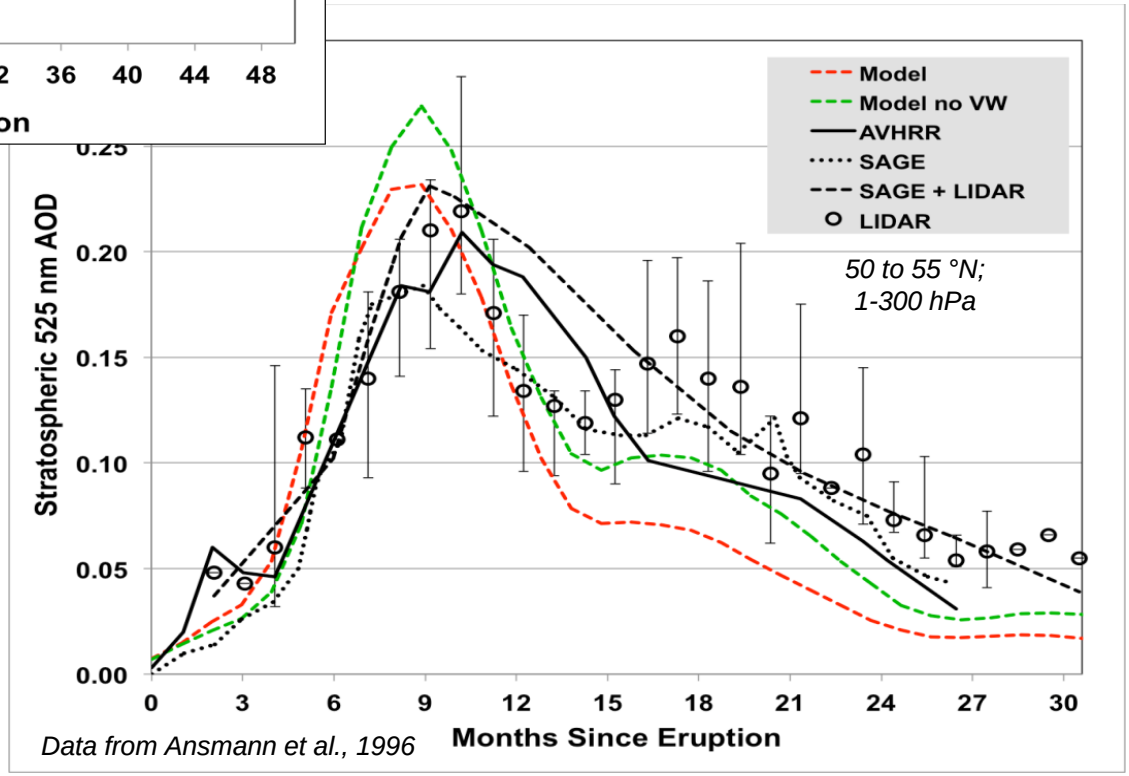




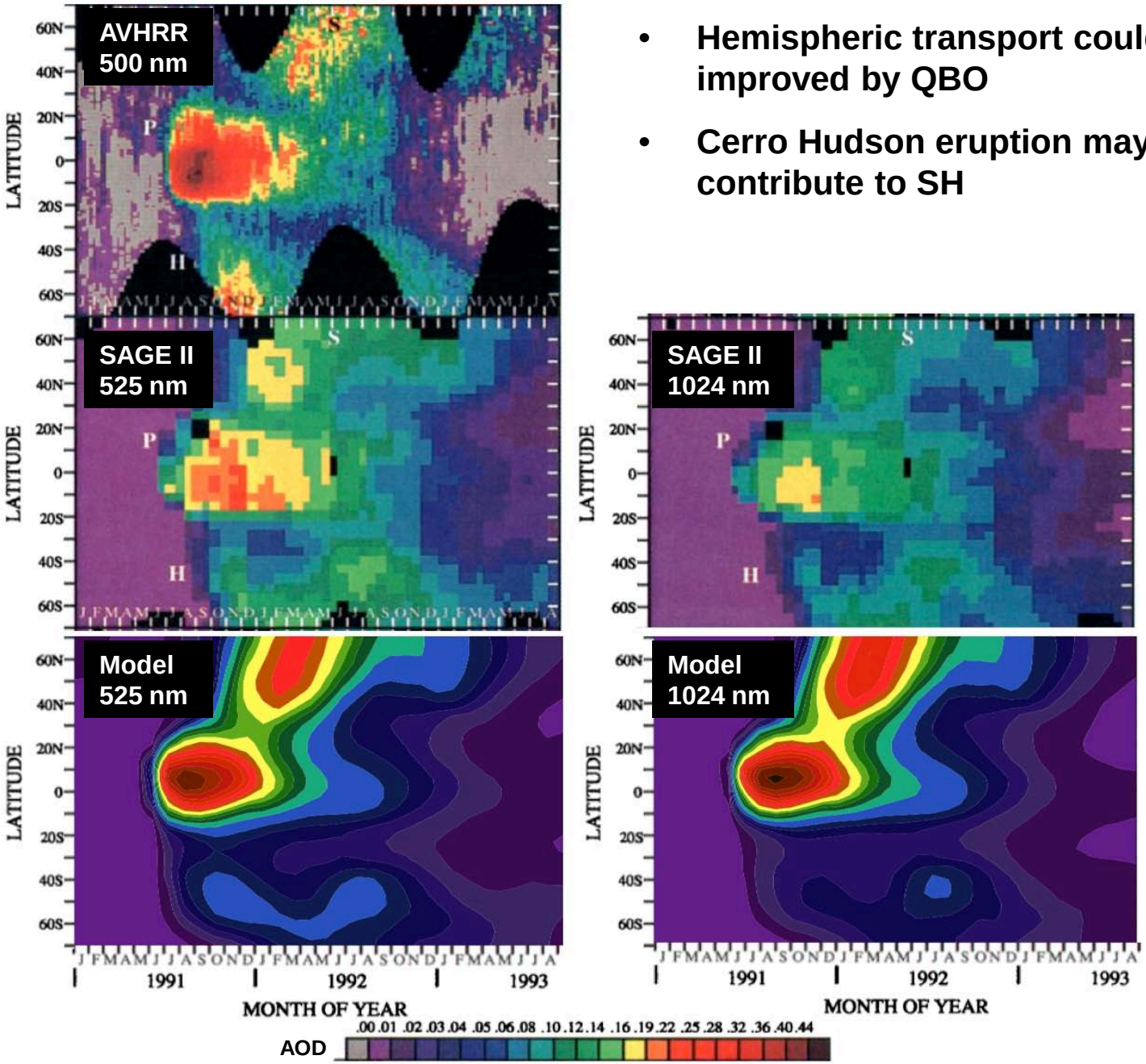
Pinatubo: Model captures peak but declines too quickly



- **Model is mostly within error bars but declines too quickly (no aerosol heating, no QBO)**
- **Including van der Waals forces increases effective radius and reduces AOD**

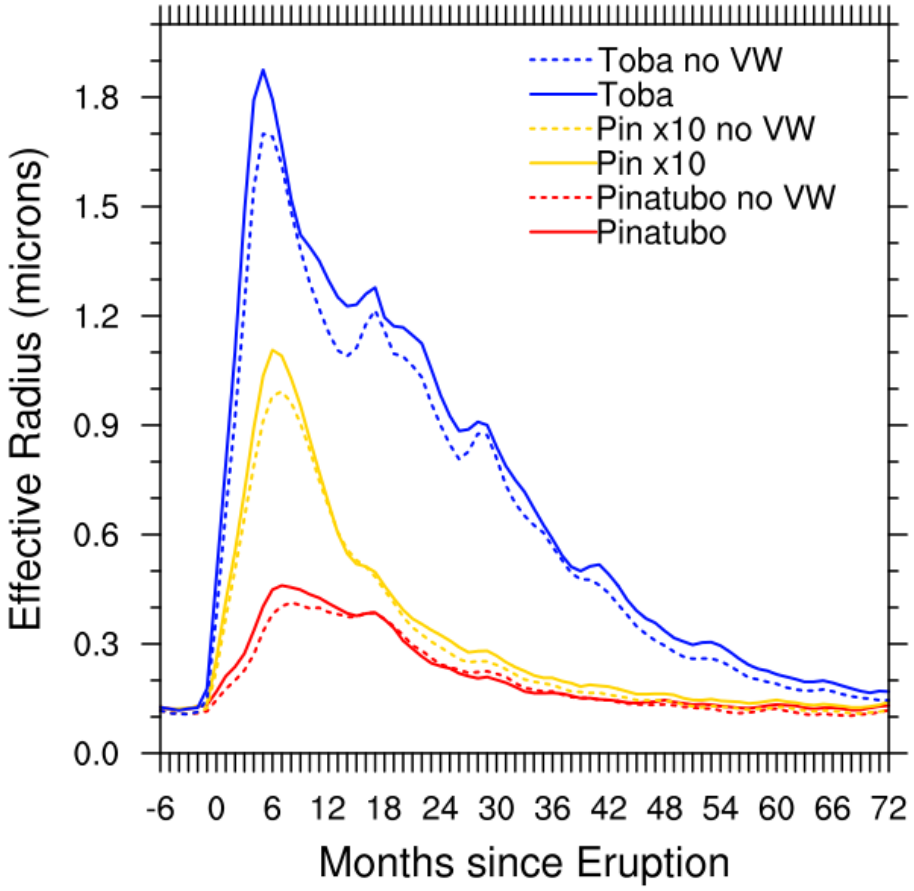


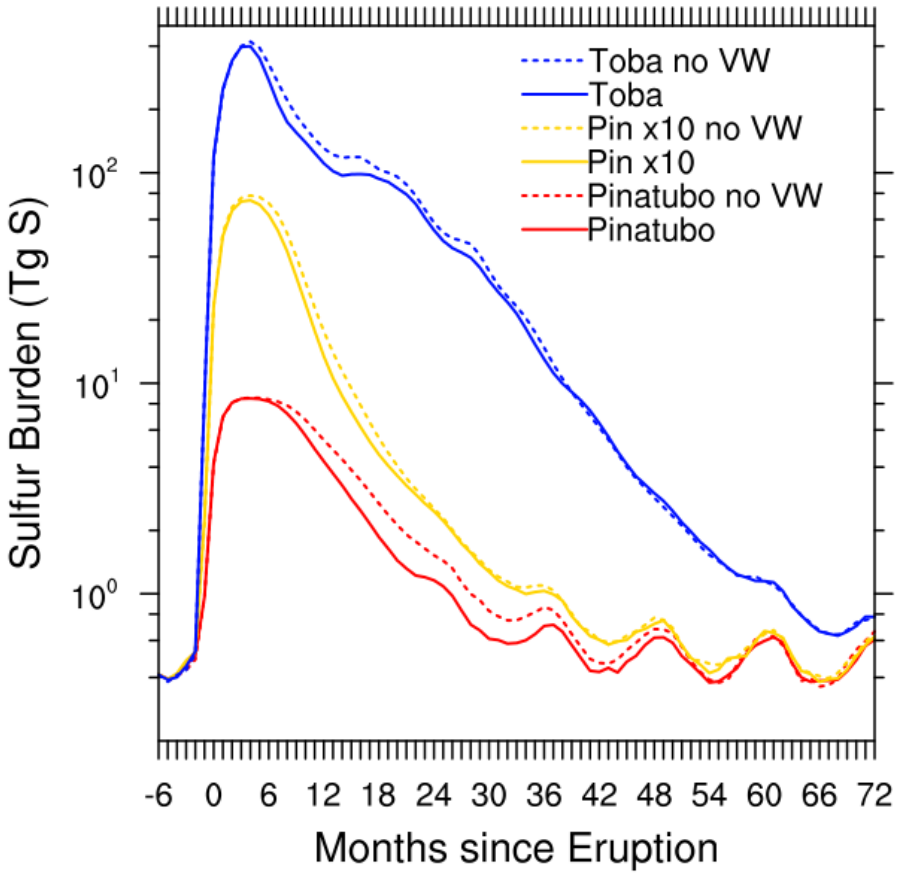
Pinatubo: Model overpredicts AOD in NH; underpredicts SH



- **Hemispheric transport could be improved by QBO**
- **Cerro Hudson eruption may contribute to SH**

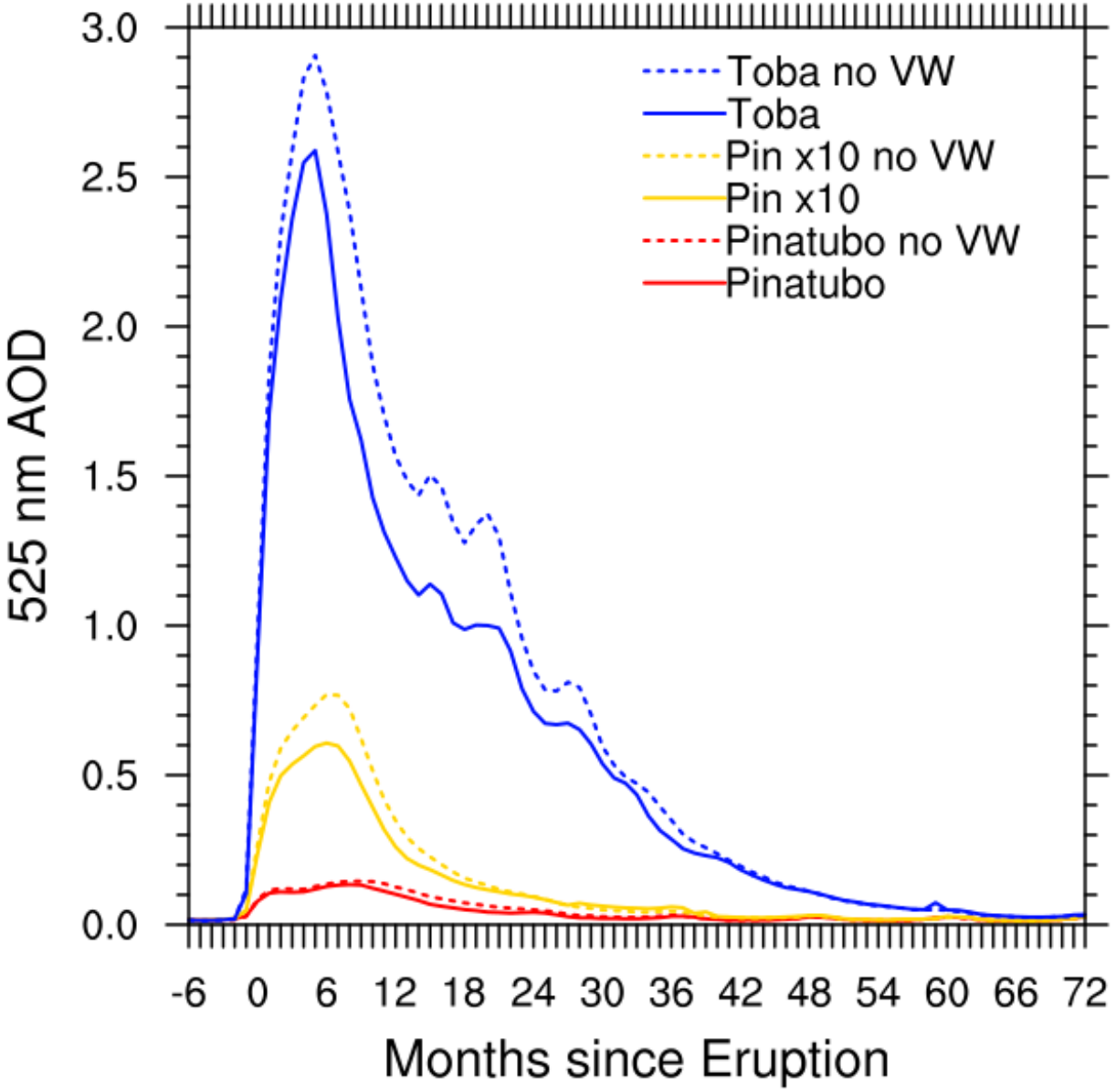
Larger Eruptions have larger particles, limited burdens



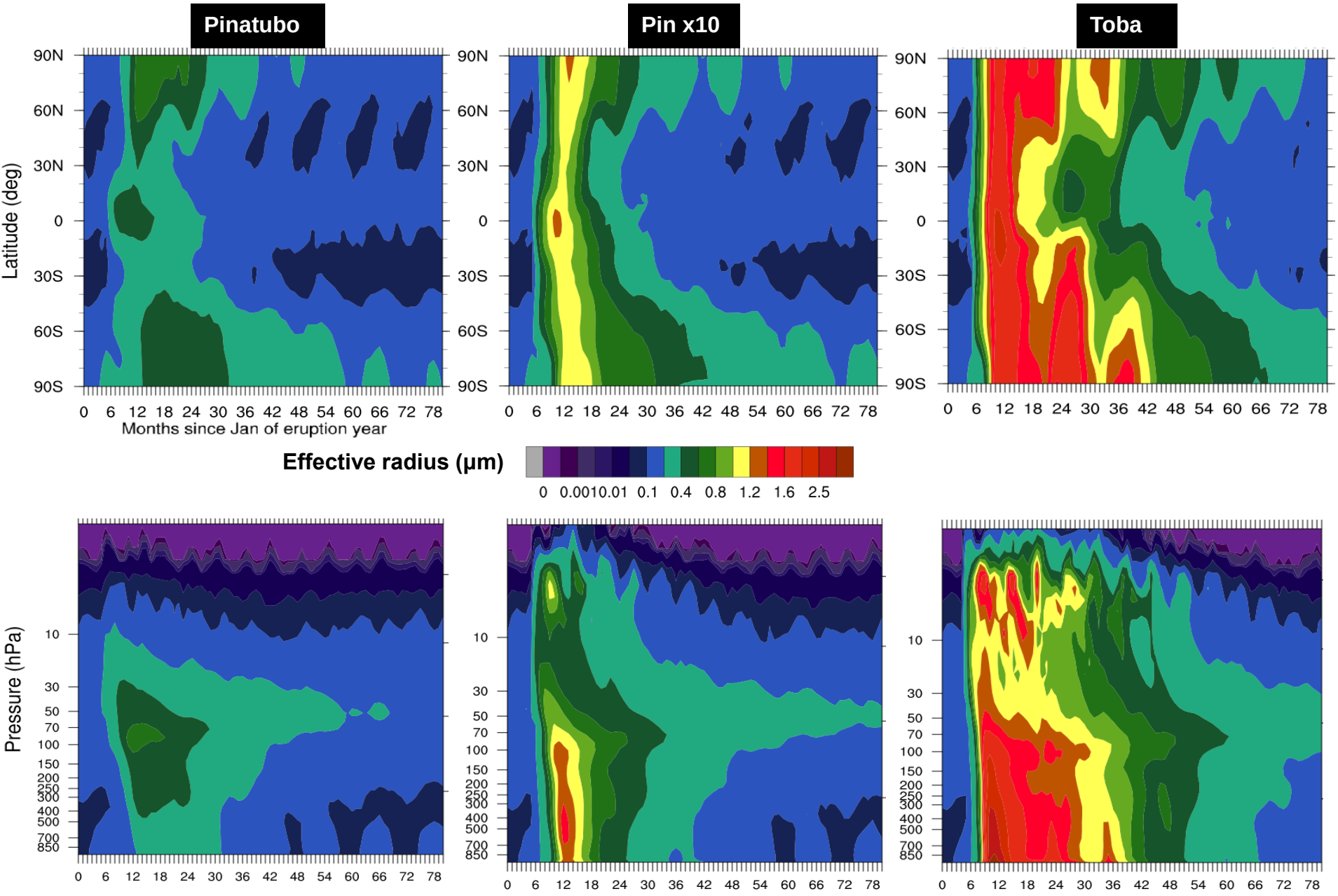


Comparing Toba Studies	Reff (um)
Robock et al., 2009 (Bulk)	~0.6 µm (0.45 dry)
Timmreck et al., 2010 (Modal)	0.8 – 1.1 µm
English et al., 2013 (Sectional)	1.1 – 2.2 µm

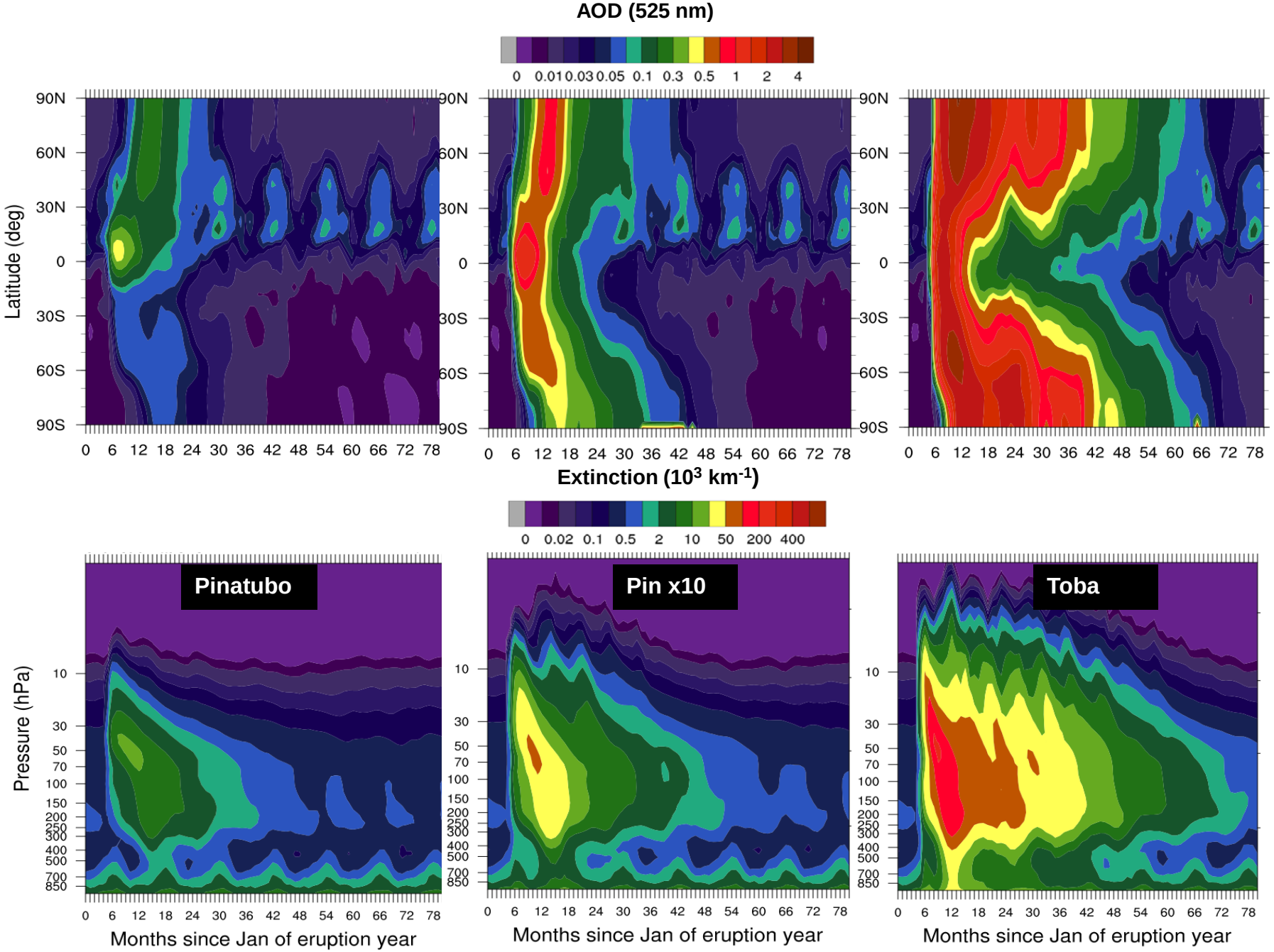
AOD is limited further in larger eruptions



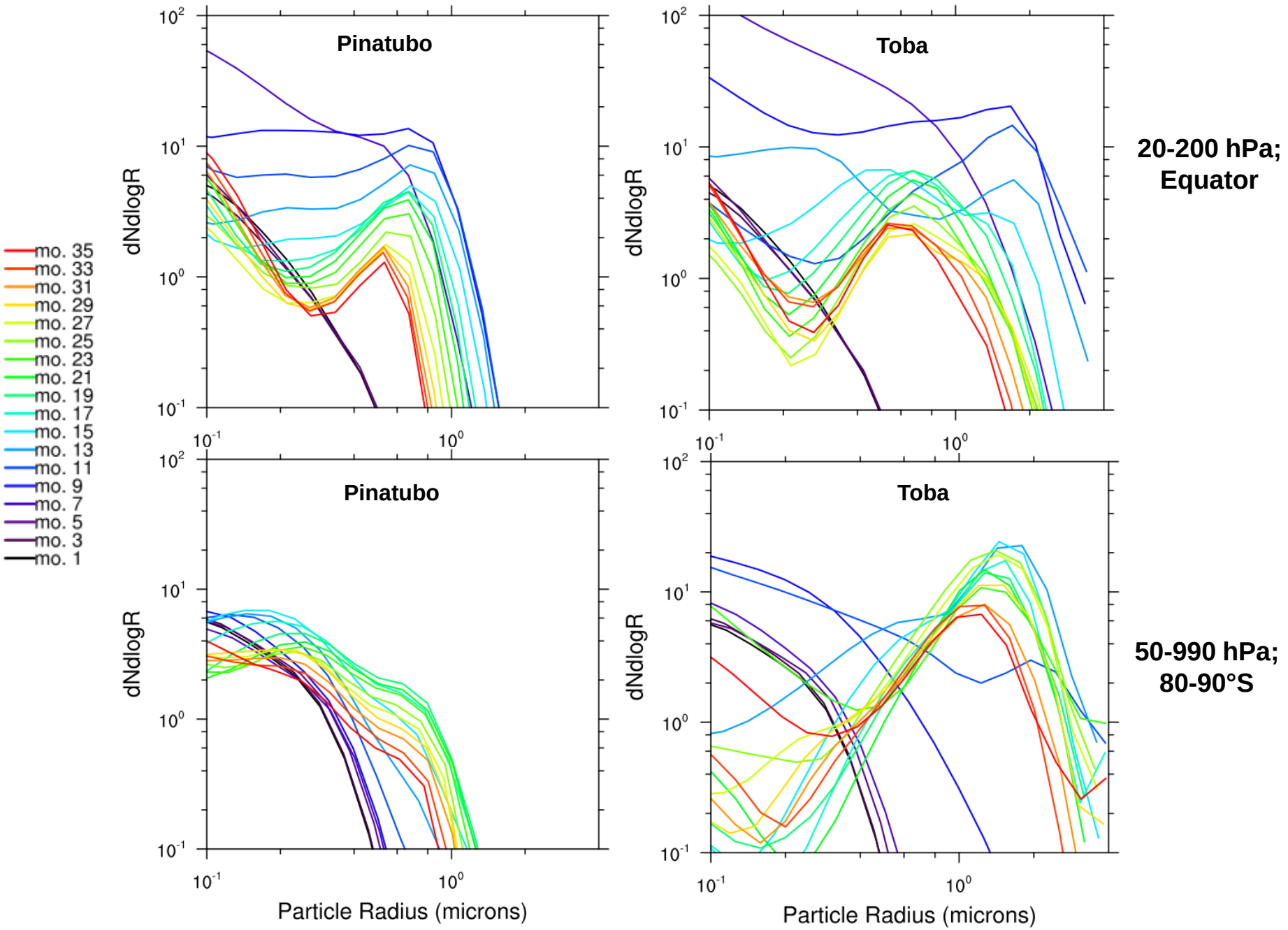
Effective radius peaks in high latitudes and below 150 hPa



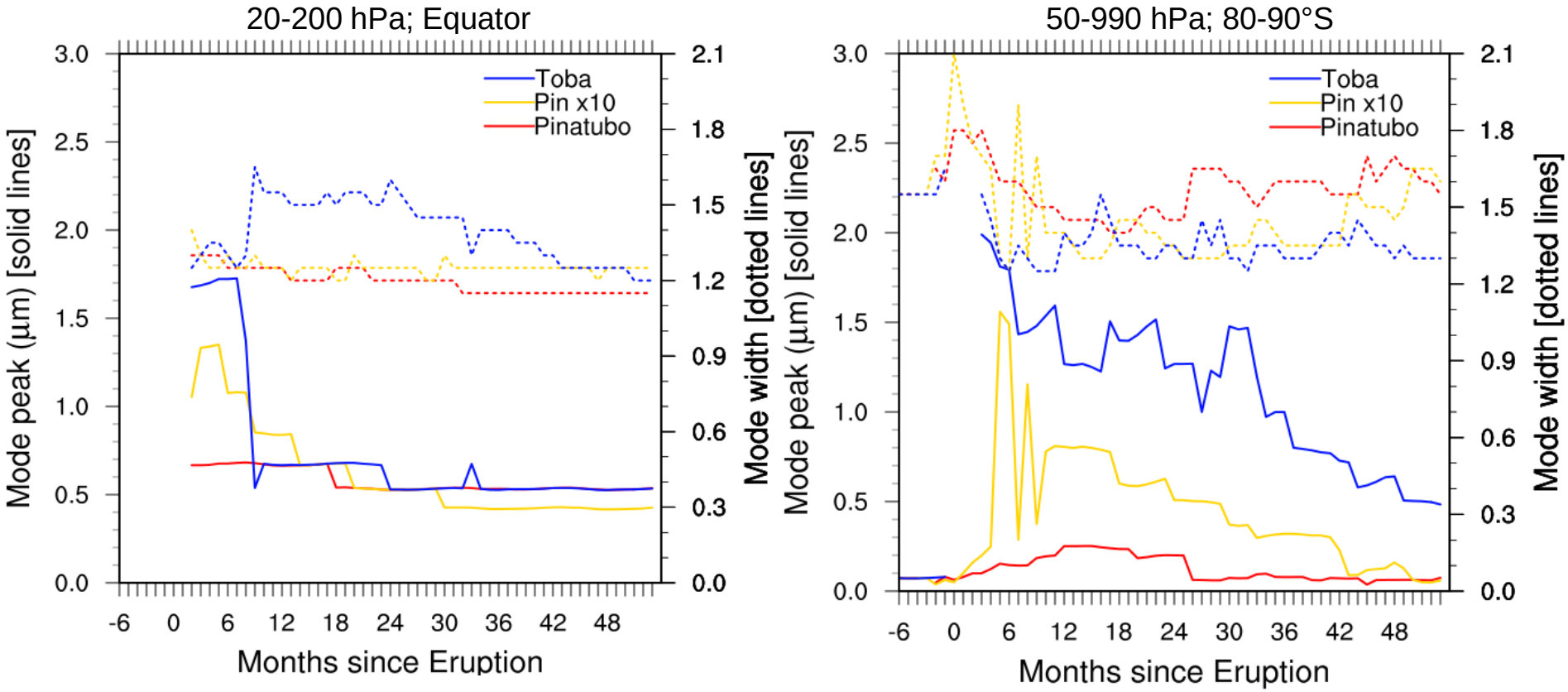
Extinctions peak in lower stratosphere and poles



Accumulation modes perturbed in tropics and at poles



Mode peaks and widths vary



Comparing Toba Studies	Mode width
Robock et al., 2009 (Bulk)	1.25
Timmreck et al., 2010 (Modal)	1.2
English et al., 2013 (Sectional)	1.2 - 2.1

Summary

- **Our Pinatubo simulations capture the observed peaks in the NH but decline too quickly and are too low in the SH**
  - Need to add QBO, aerosol heating, Cerro Hudson to the model
- **Large eruptions have self-limiting radiative effects due to increased particle size**
  - Toba (100x Pinatubo) has only 50x burden; 20x AOD; 5-yr AOD and 2.0 μm reff
- **Accumulation mode peak and widths evolve in a complex manner; 2-moment modal models may not be accurate**
  - Mode widths vary from 1.2 to 2.1
  - High latitude mode peak varies from 2 um to 0.5 um over 4 years

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