Impacts of stratospheric sulfate geoengineering on tropospheric sulfate burdens

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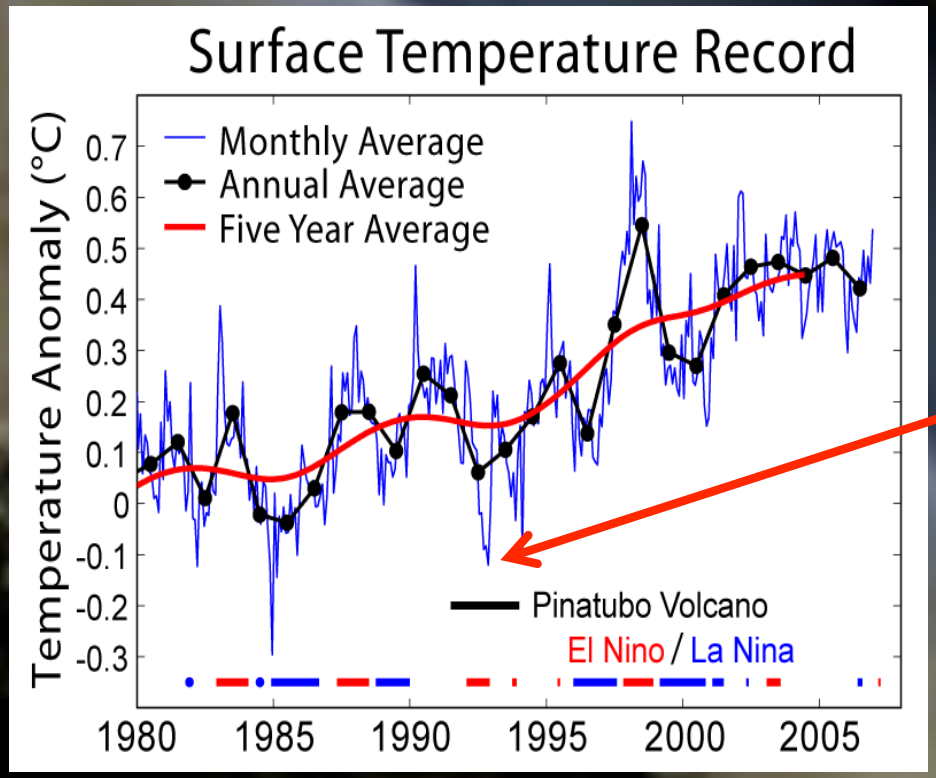
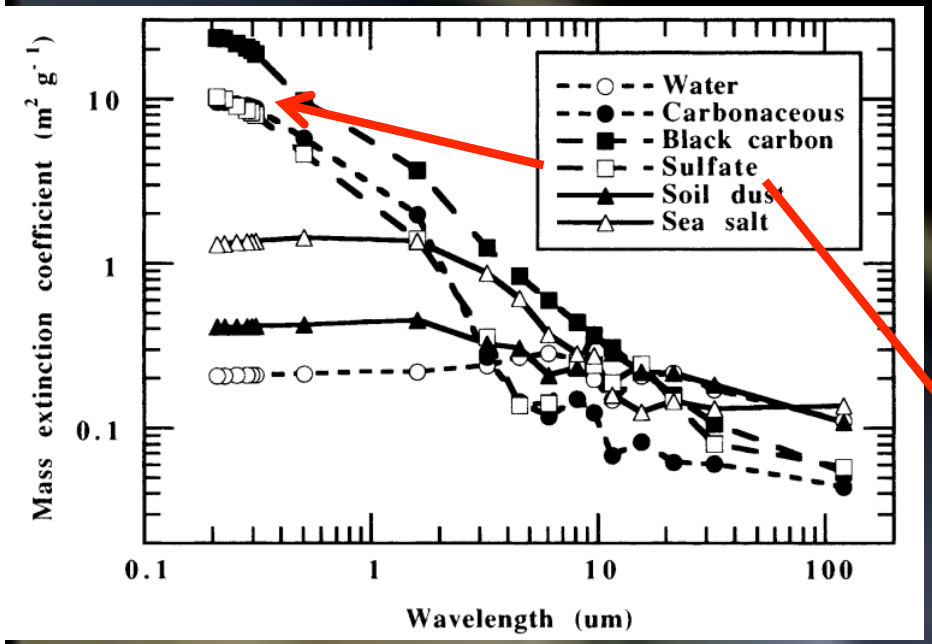
Mt. Pinatubo (1991) demonstrated cooling

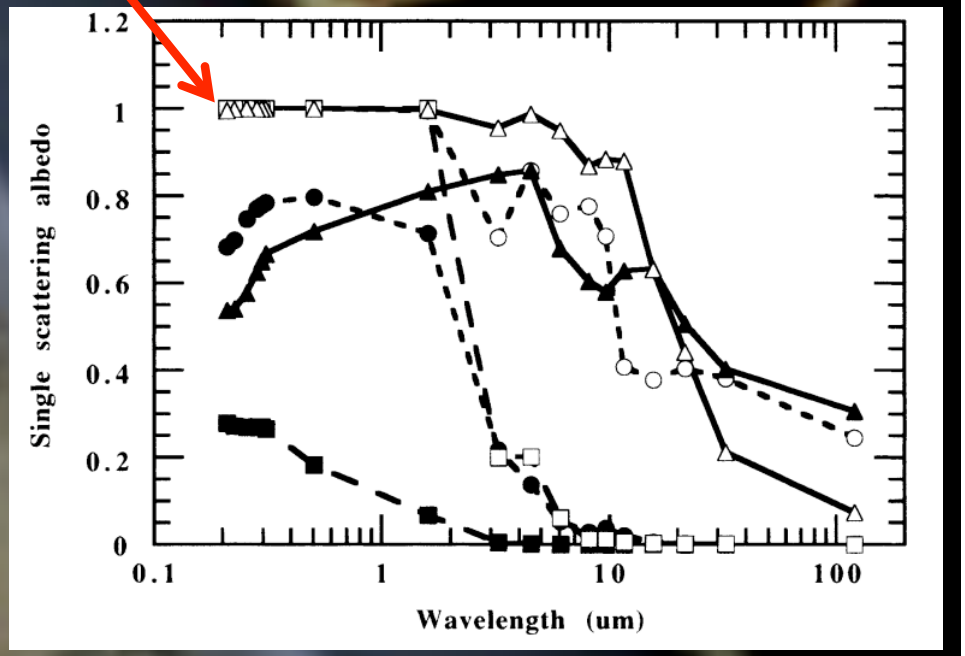


- 1992: Temperature dropped 0.5°C; coolest year in the past 25 years
- We also saw ozone loss, hydrological changes

Why are sulfate aerosols so special?



Sulfates have high extinction (ability to reflect and absorb radiation)

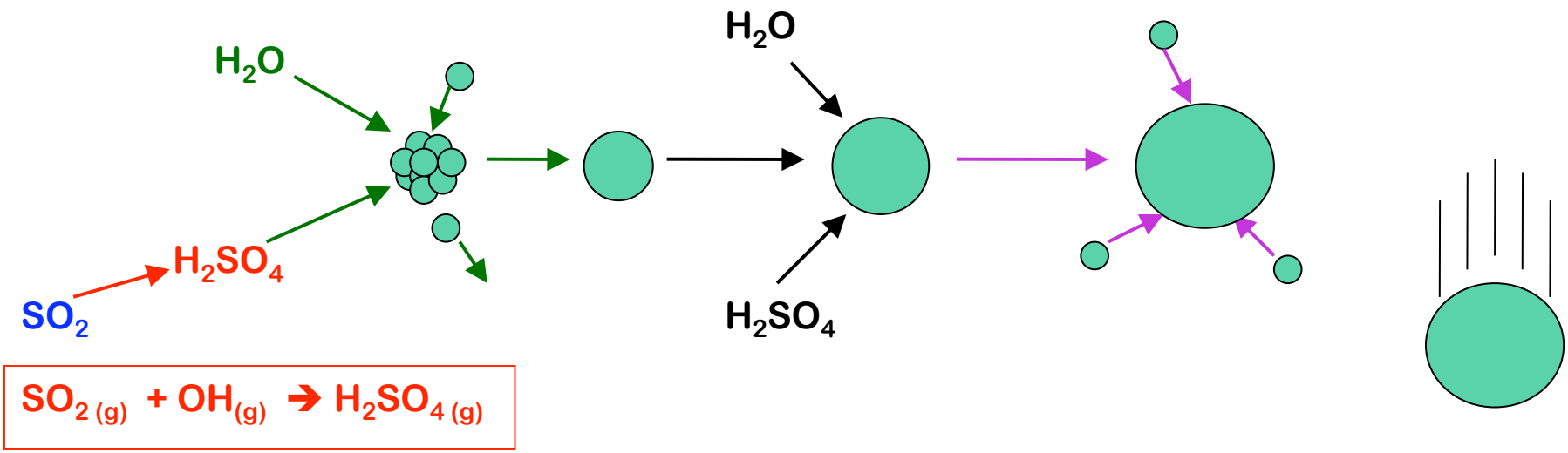


Sulfates have high Single Scattering Albedo (they prefer to reflect radiation rather than absorb it)

What does SO_2 have to do with sulfate aerosols?

The sulfate aerosol life cycle

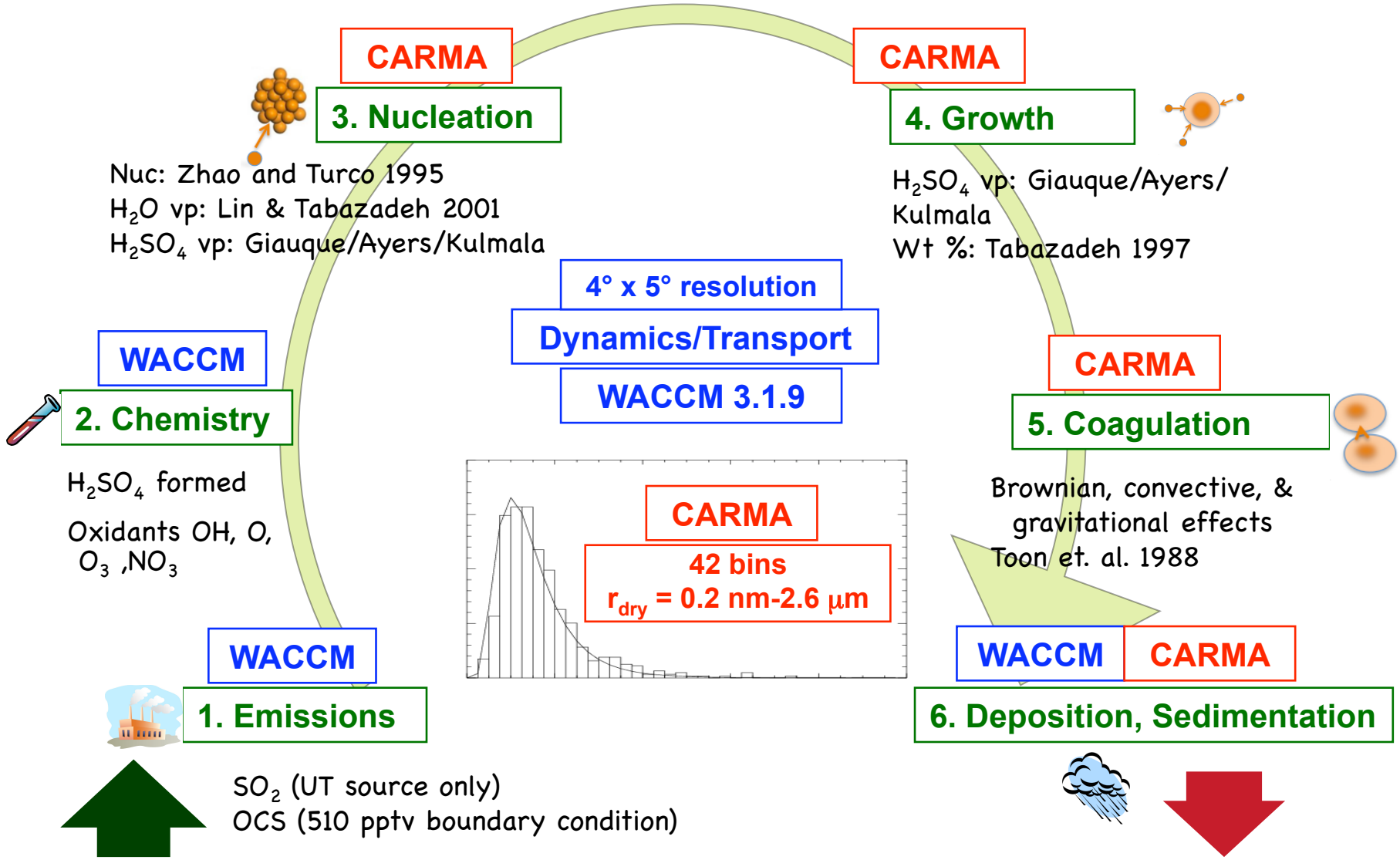
1. emissions	2. chemistry	3. nucleation	4. growth	5. coagulation	6. deposition
Mt. Pinatubo (20 Tg SO_2), geoengineering (? Tg SO_2)	Sulfuric acid is made	an aerosol is born	evaporation, condensation	particles collide and combine	particles fall to the earth



$SO_{2\,(g)} + OH_{(g)} \rightarrow H_2SO_{4\,(g)}$

Most climate models parameterize some of these processes (esp. nucleation, growth, coagulation)

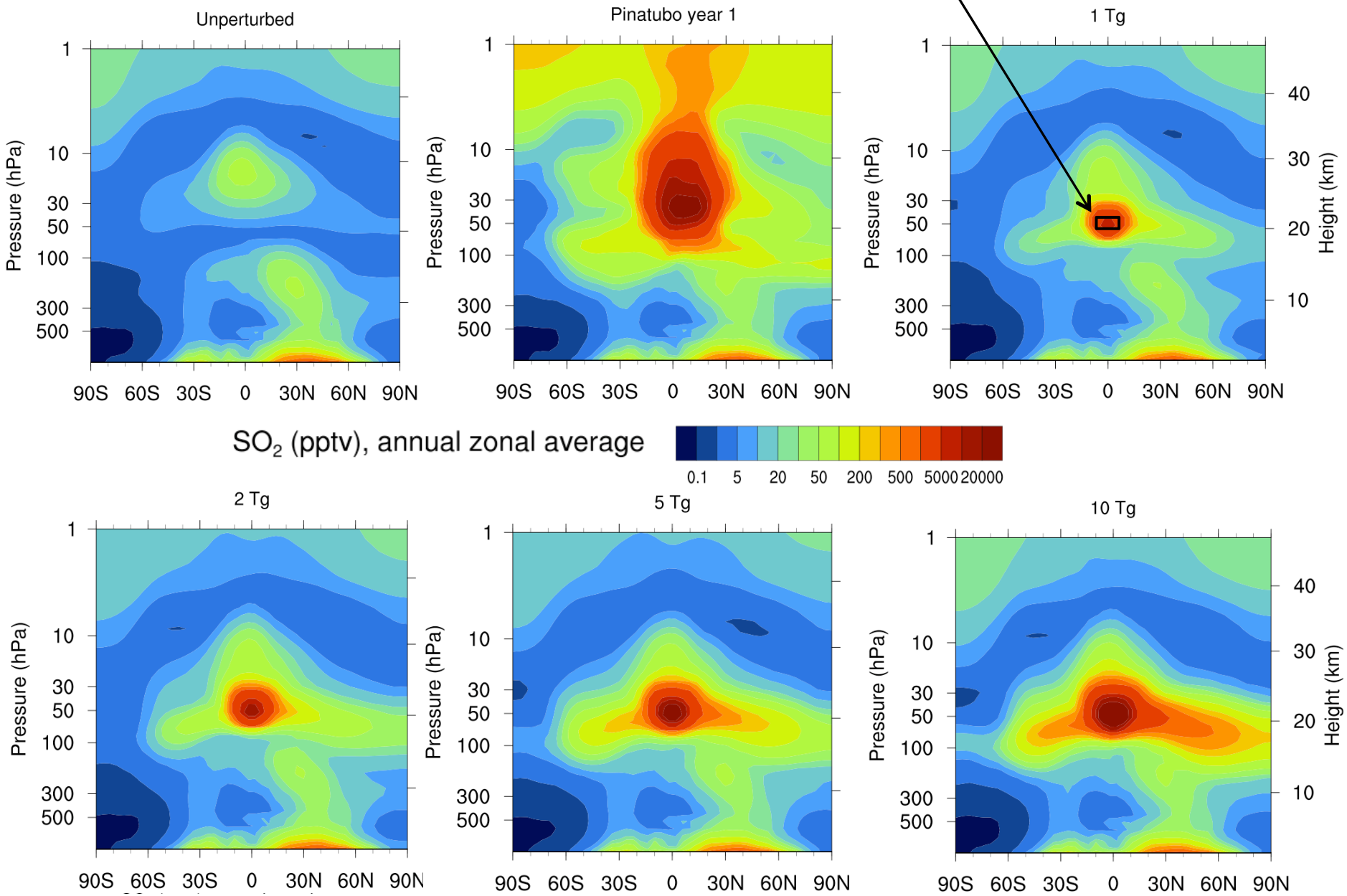
WACCM/CARMA Coupled Model



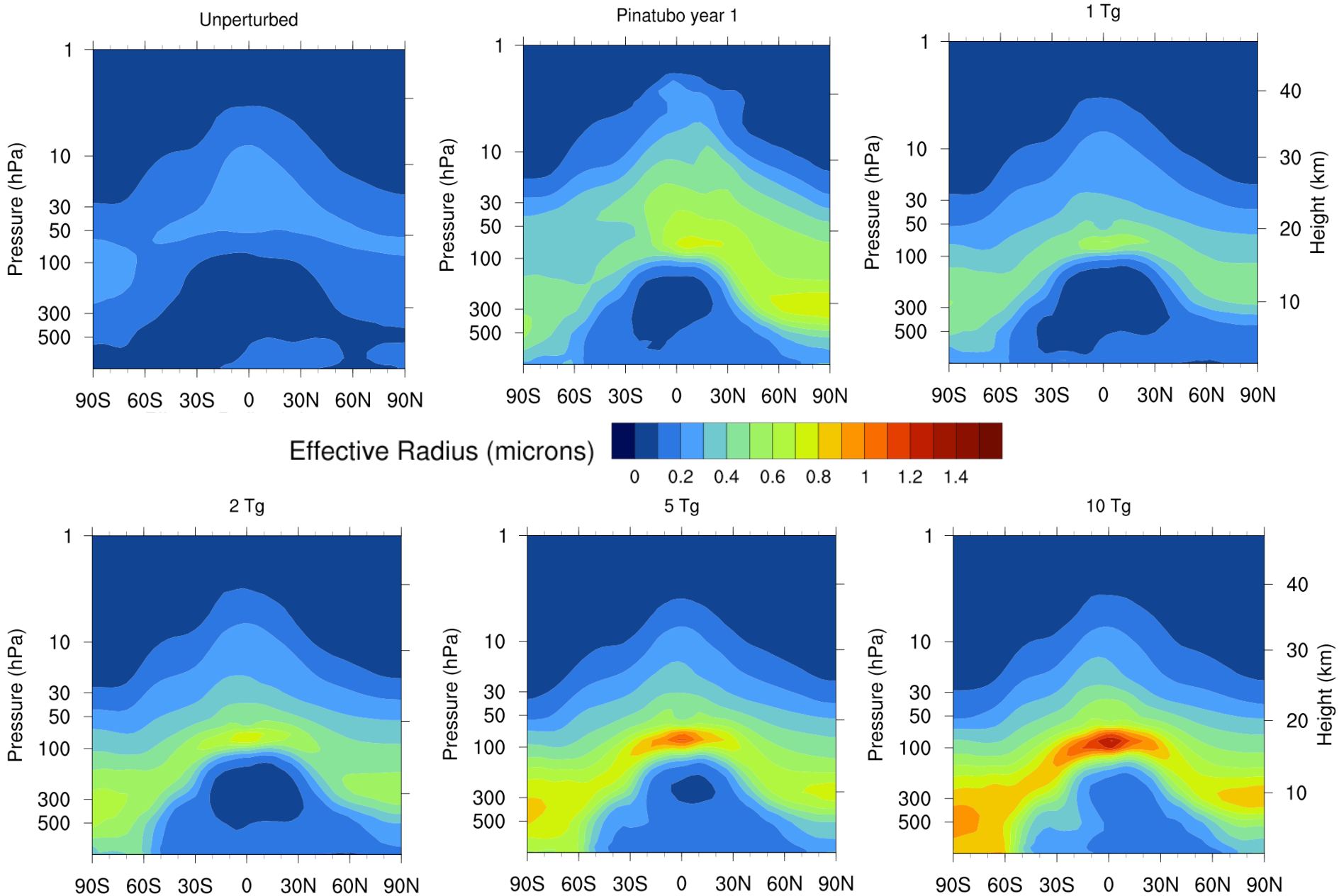
Aerosol radiative effects not coupled, but het chem is

5 year simulations; 5th year analyzed

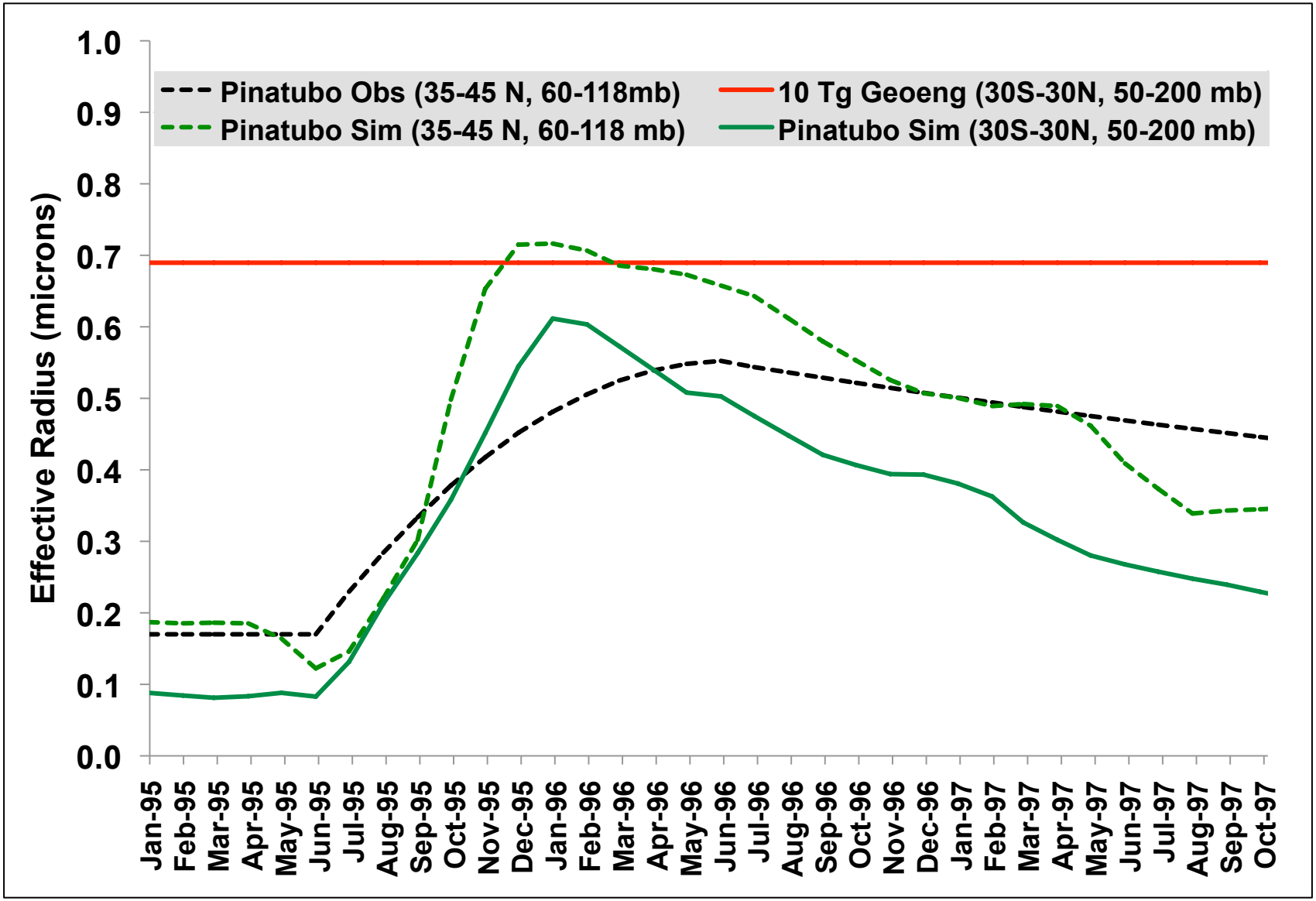
Five SO_2 injection schemes (50 mb, 4N-4S, all longitudes)



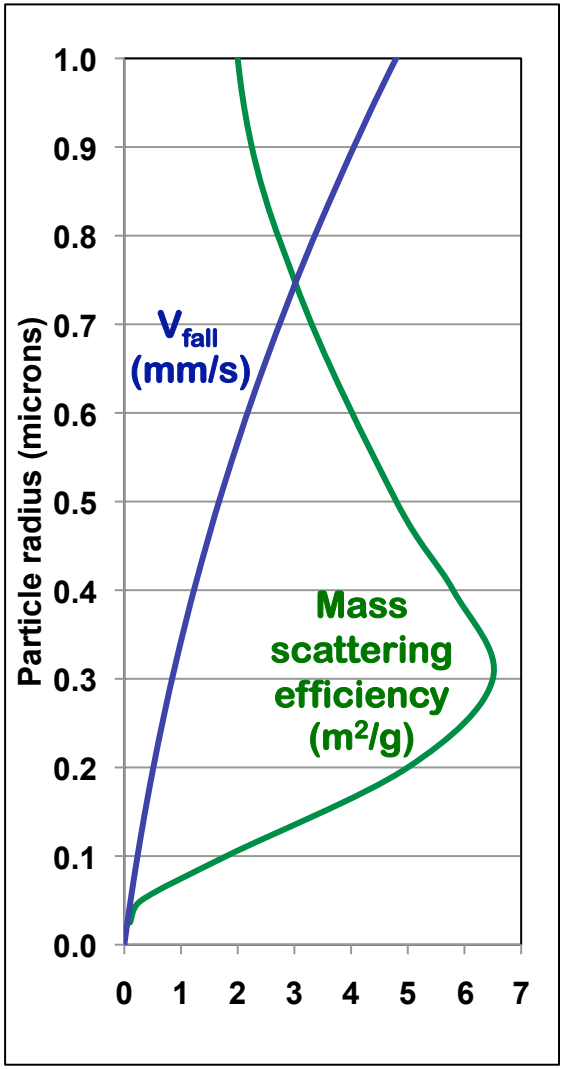
Geoengineered effective radius is larger

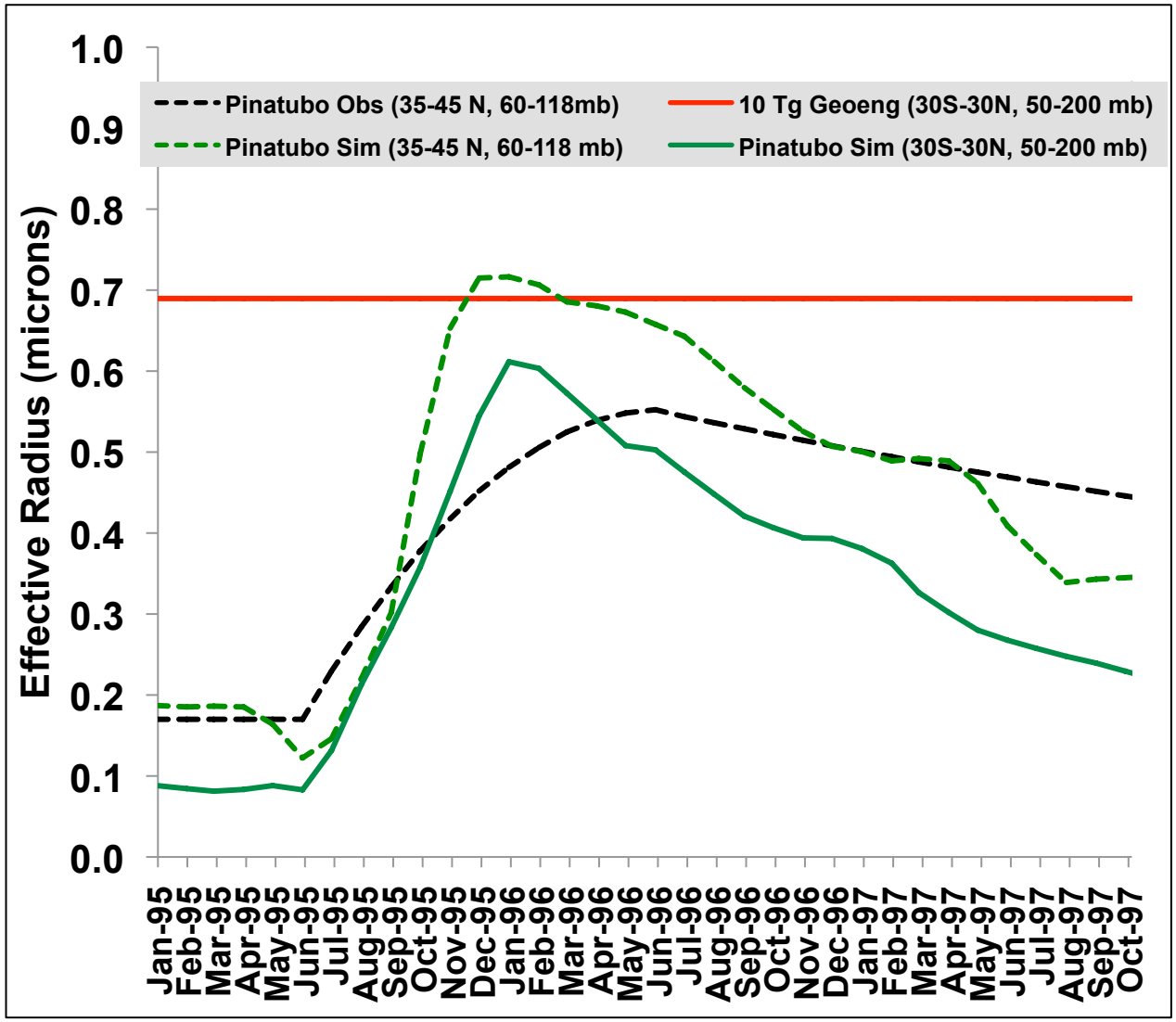


Simulated Pinatubo R_{eff} reaches peak sooner than obs; Simulated Geoeng R_{eff} larger than Pinatubo



Larger particles fall faster and RF less effective





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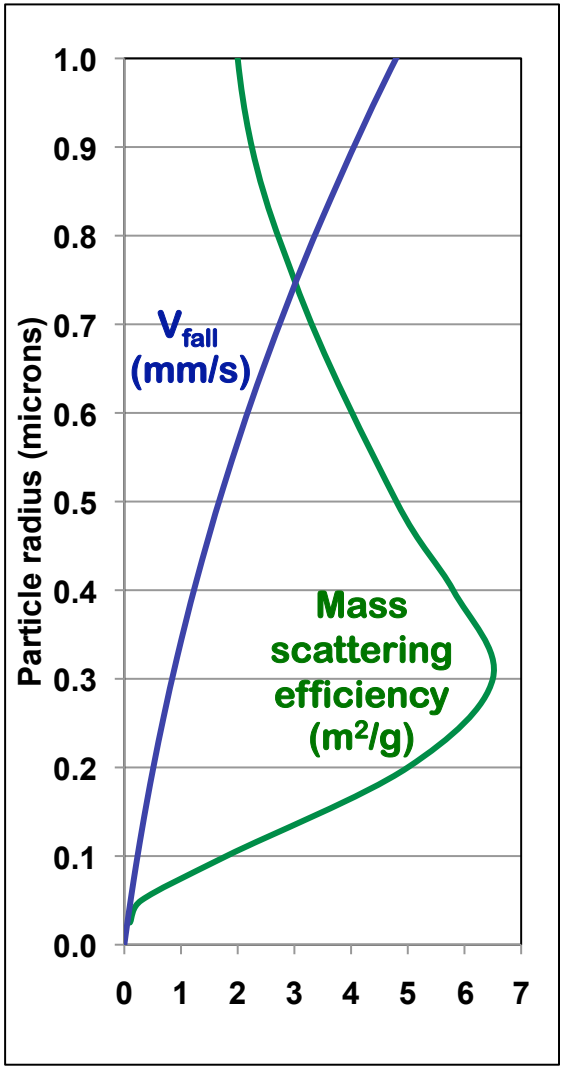
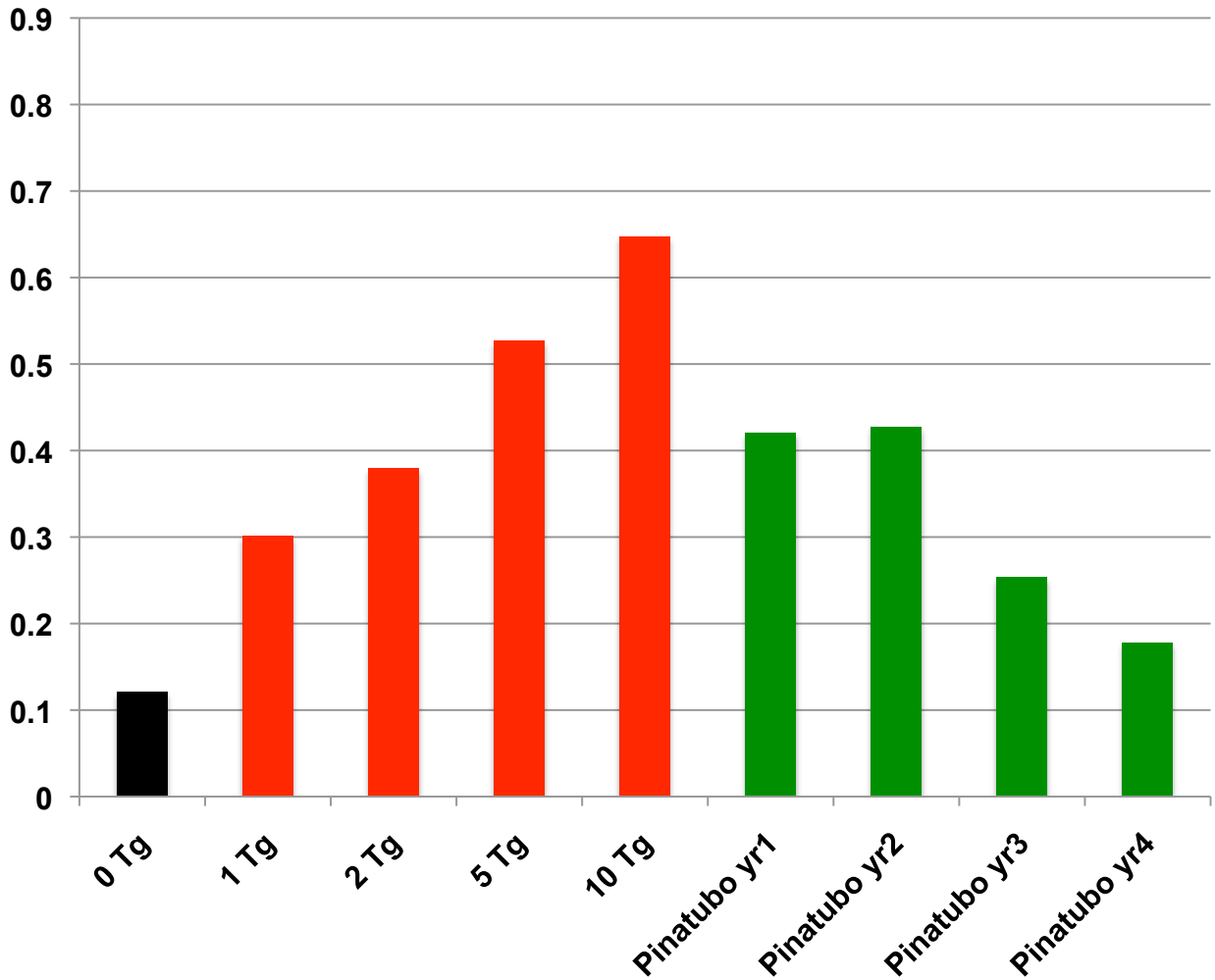
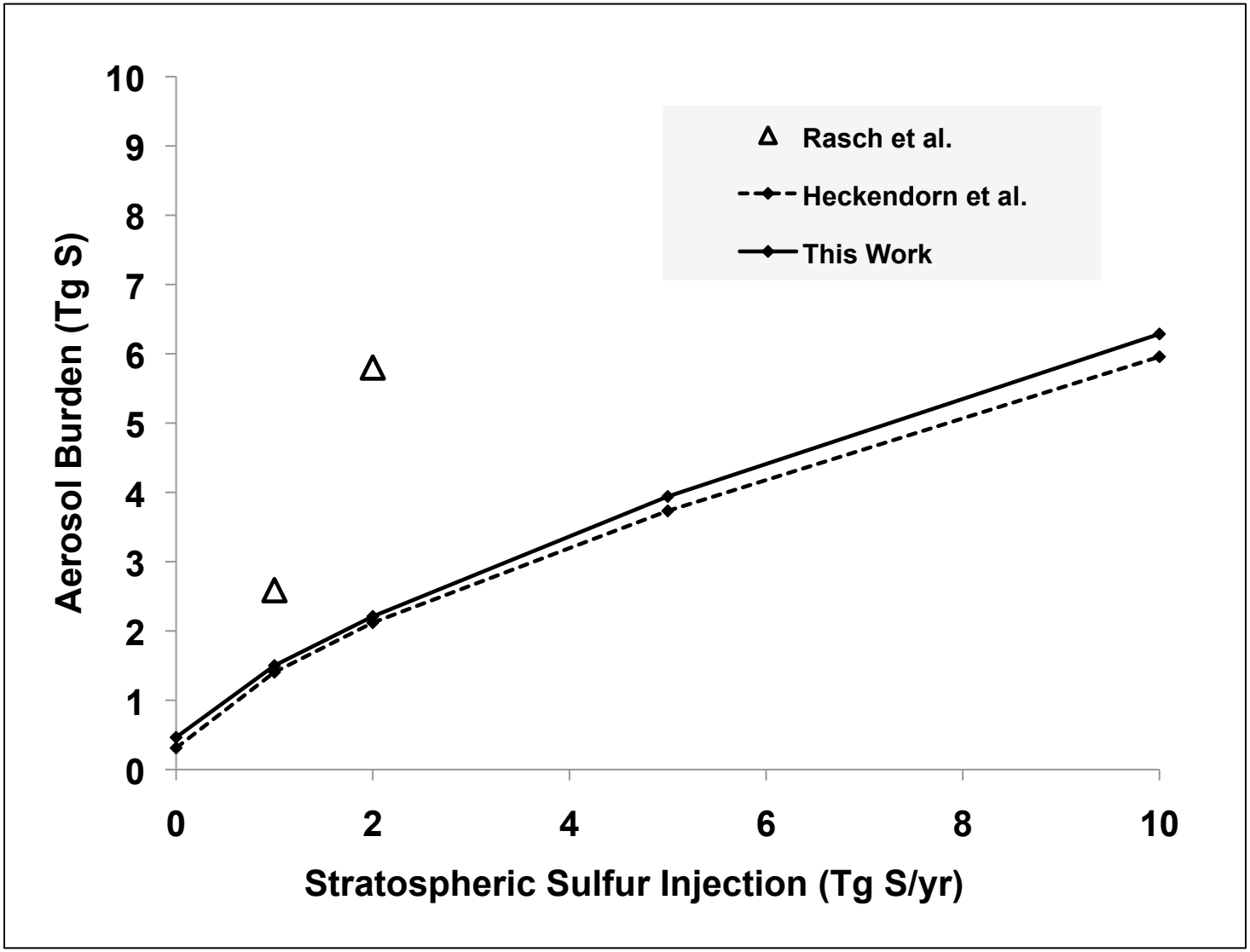
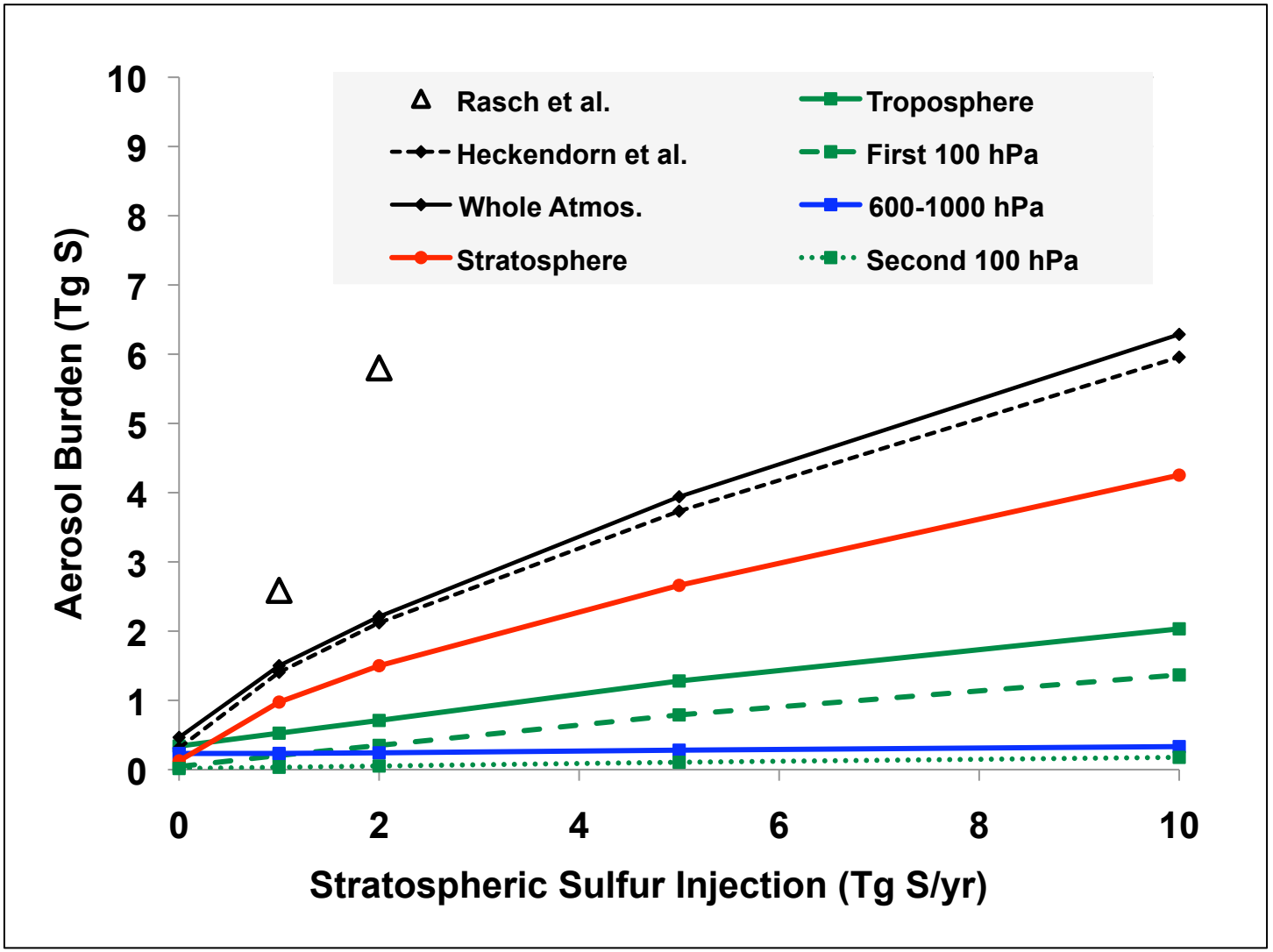




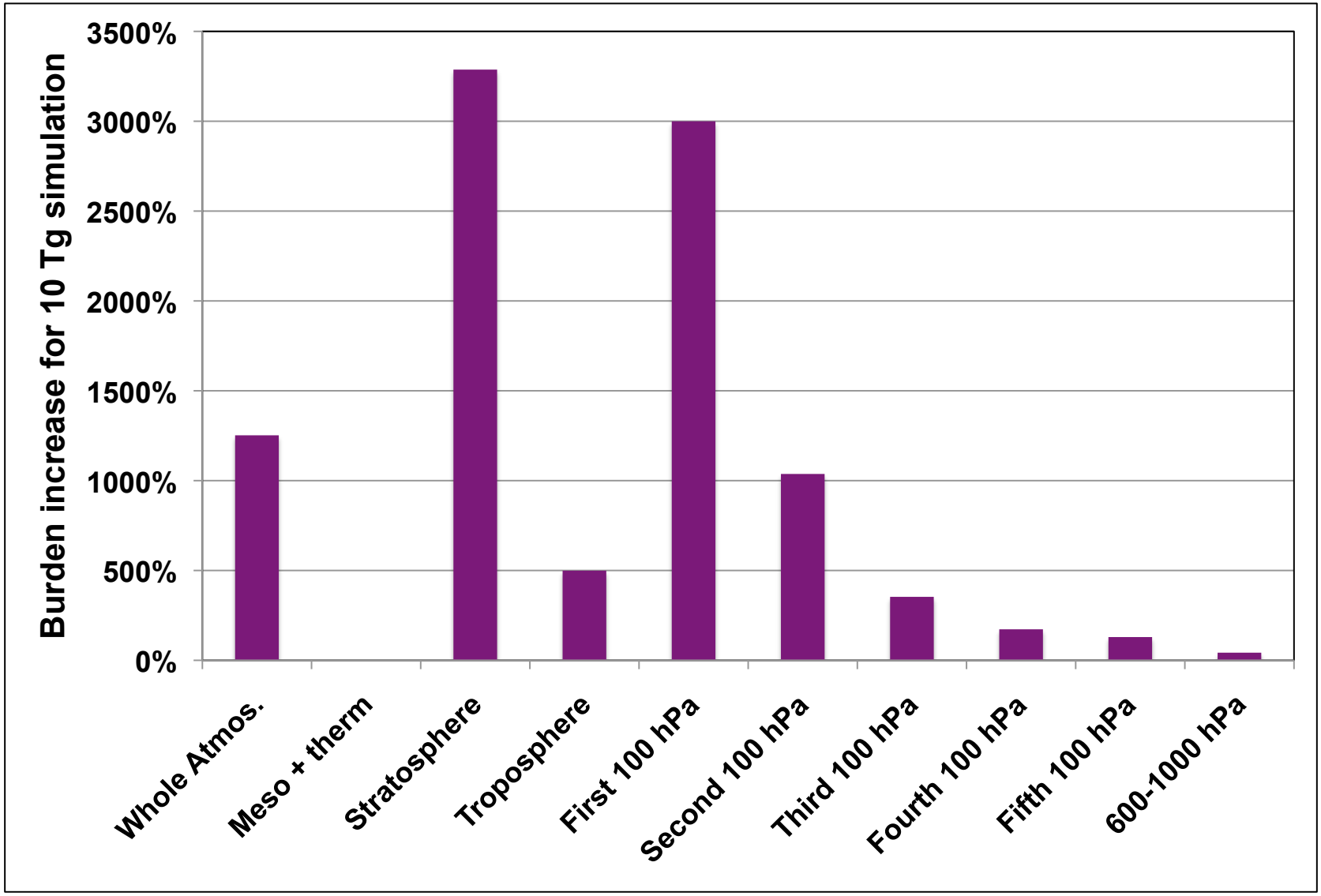
Two microphysical studies compare well, and differ significantly from GCM-only simulations



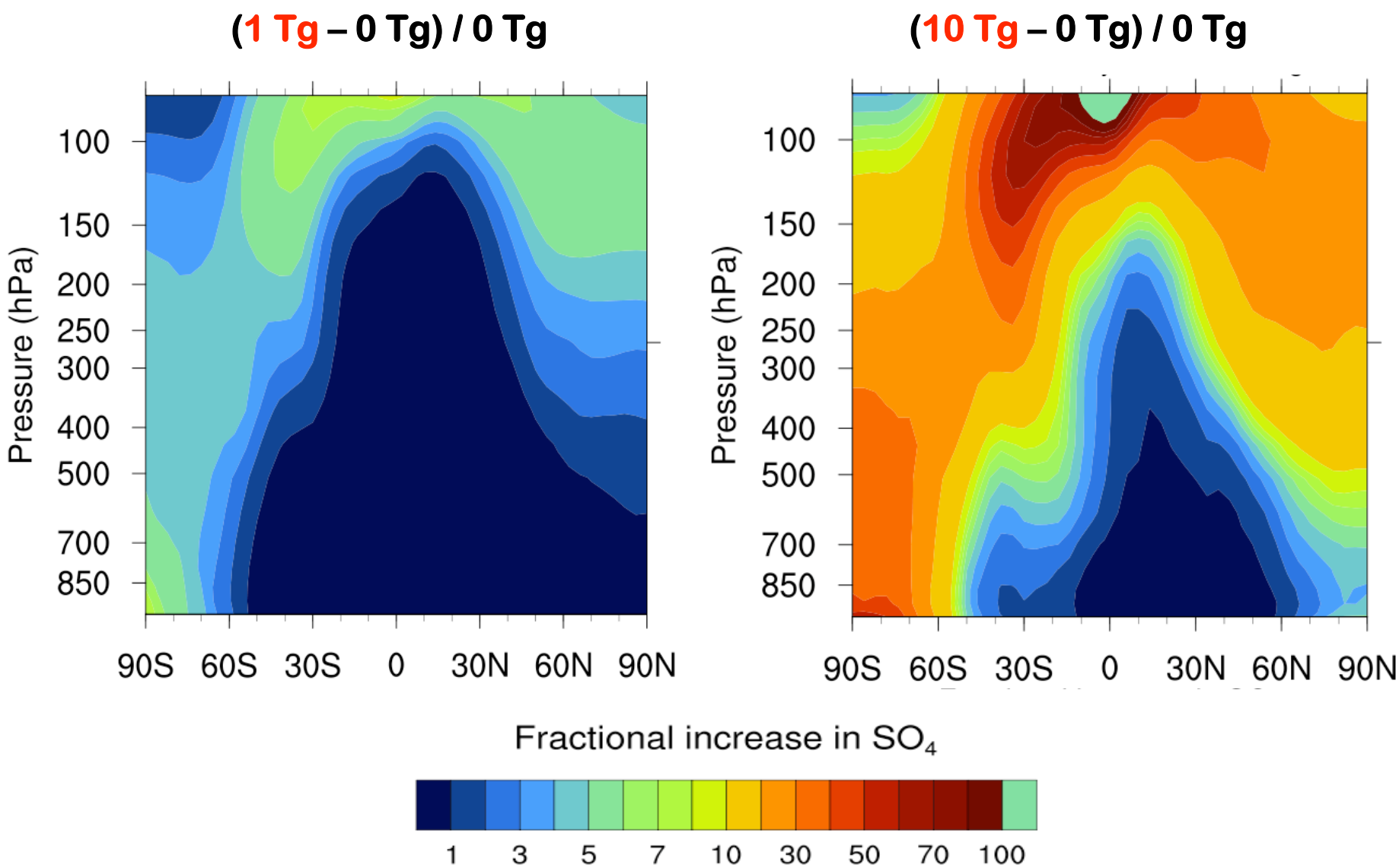
1/3 of total burden is in the troposphere; 1/3 of that is in the first 100 hPa below the tropopause



10 Tg injection increases upper 100 hPa burden by 30x



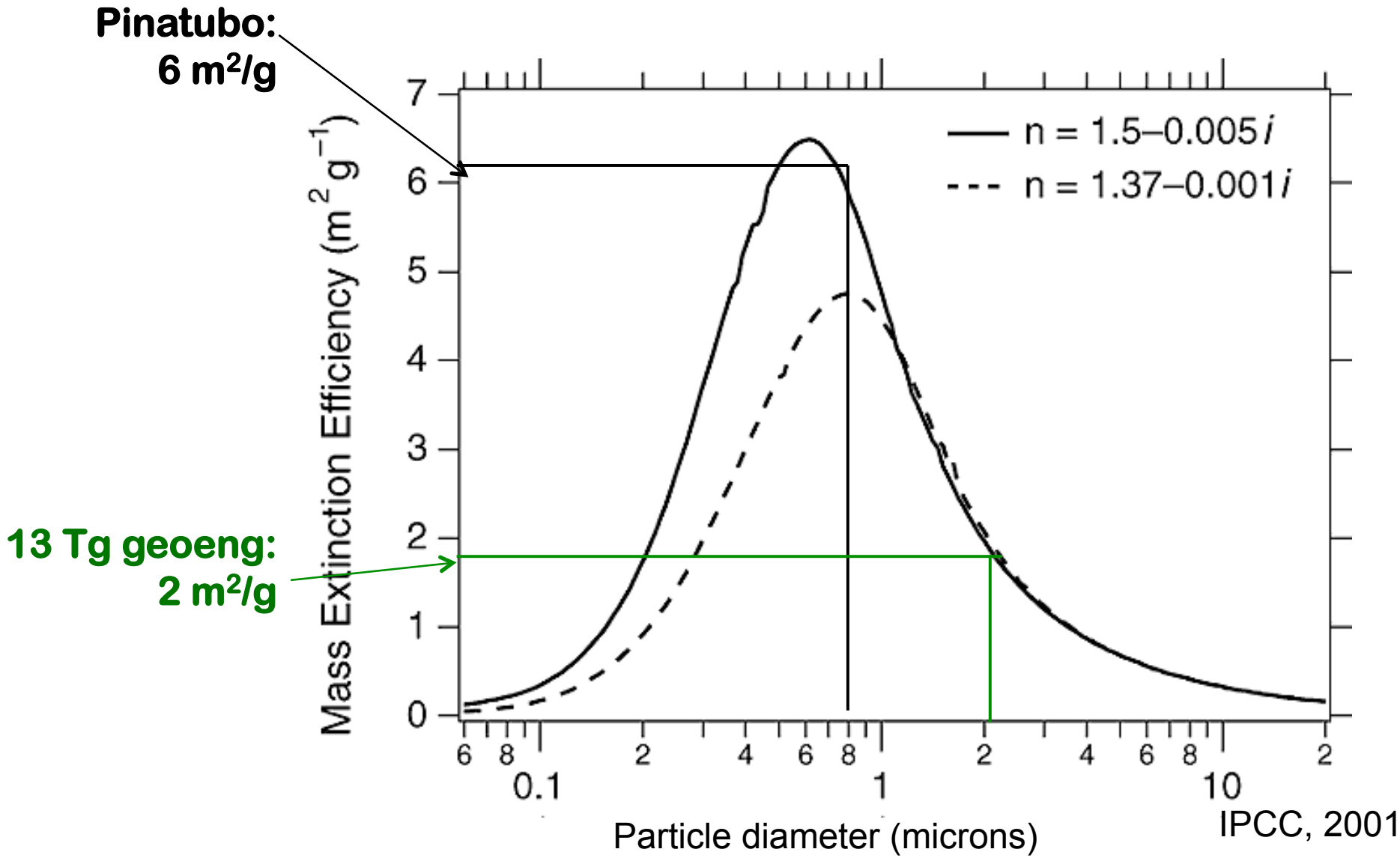
Geoeng increases tropospheric burden in the upper troposphere and high latitudes up to 100x



Our 3D microphysical simulations of stratospheric SO_2 injection suggest…

- Geoengineered effective radius is larger than Pinatubo; shorter lifetime limits aerosol burden to ~6 Tg burden (~2 W m^{-2})
  - Results compare favorably to Heckendorn et al.
- Geoeng increases tropospheric aerosol burden, especially high altitude and latitude
  - Troposphere increases 5x; upper troposphere by 30x; high latitudes by 30x
  - Could impact tropospheric clouds, radiative forcing, and chemistry
- Other consequences previously identified:
  - Ozone destruction / stratospheric chemistry changes
  - Acid deposition in mid/high latitudes
  - Hydrological changes/reduced precipitation
- Stratospheric lifetime may be increased by
  - Sulfur sources with slower conversion to aerosol
  - Other aerosol types
  - Higher injection / more spread out

…And the particles that are there, aren't as effective at scattering radiation



IPCC, 2001