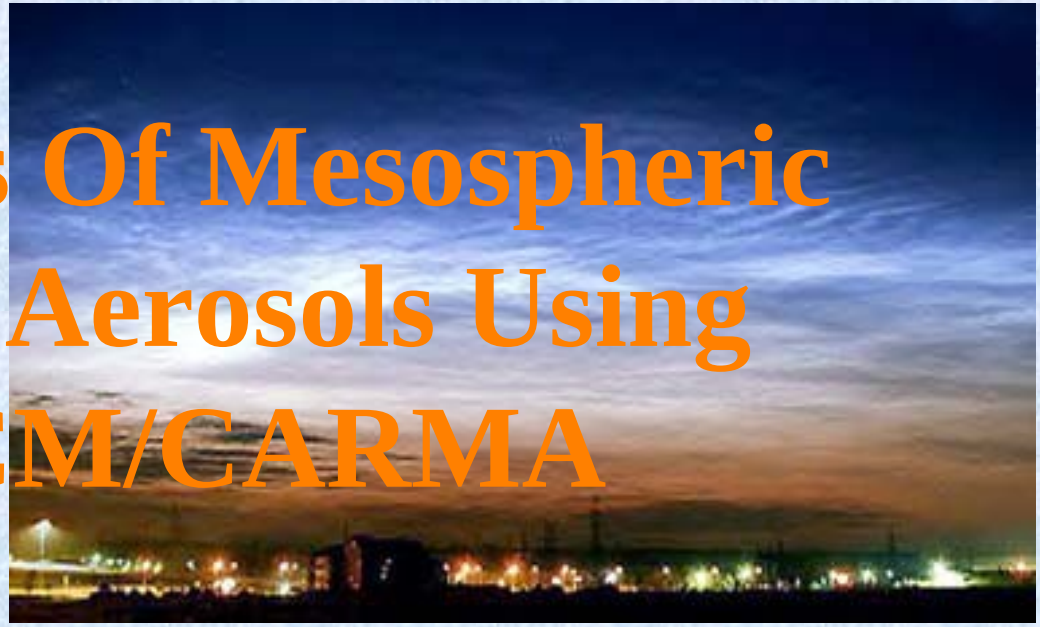
Simulations Of Mesospheric Clouds & Aerosols Using WACCM/CARMA



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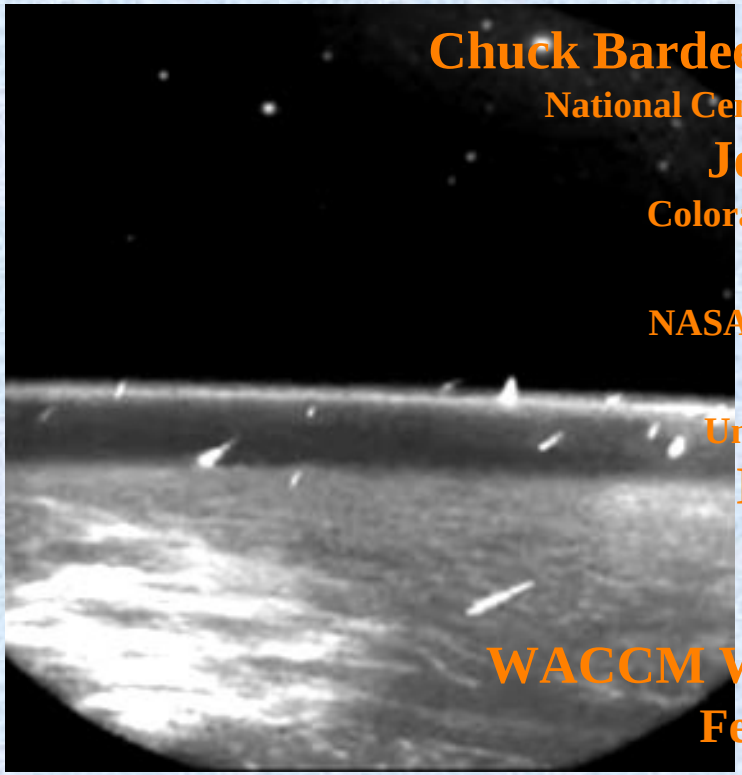
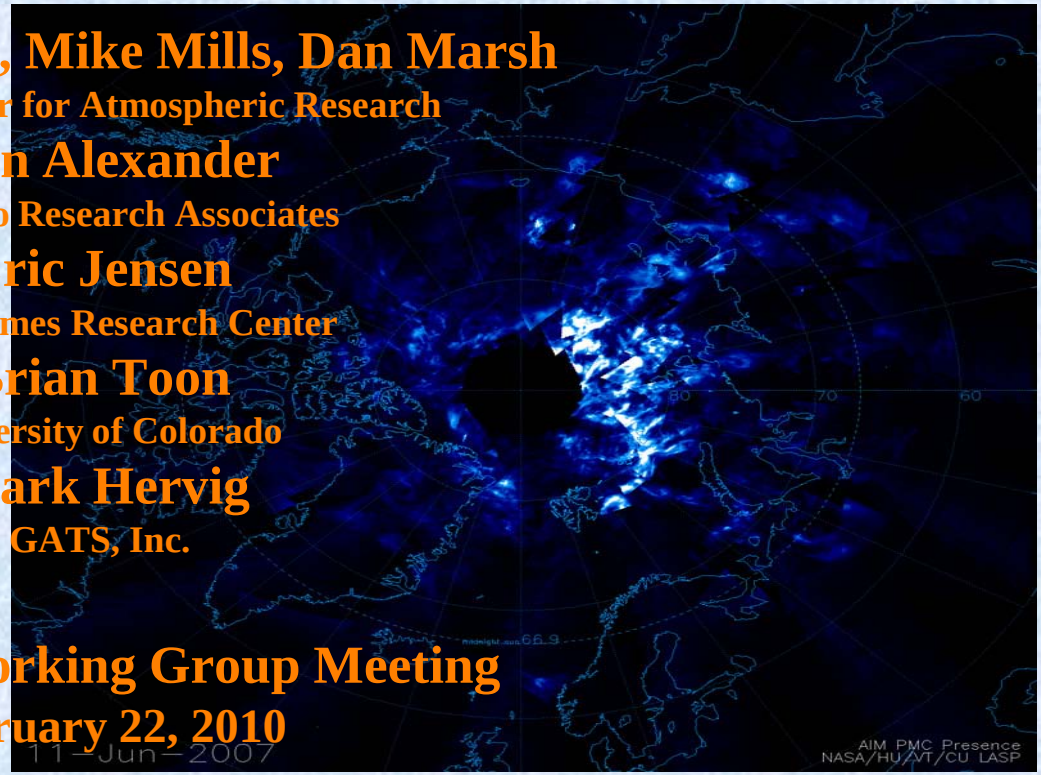
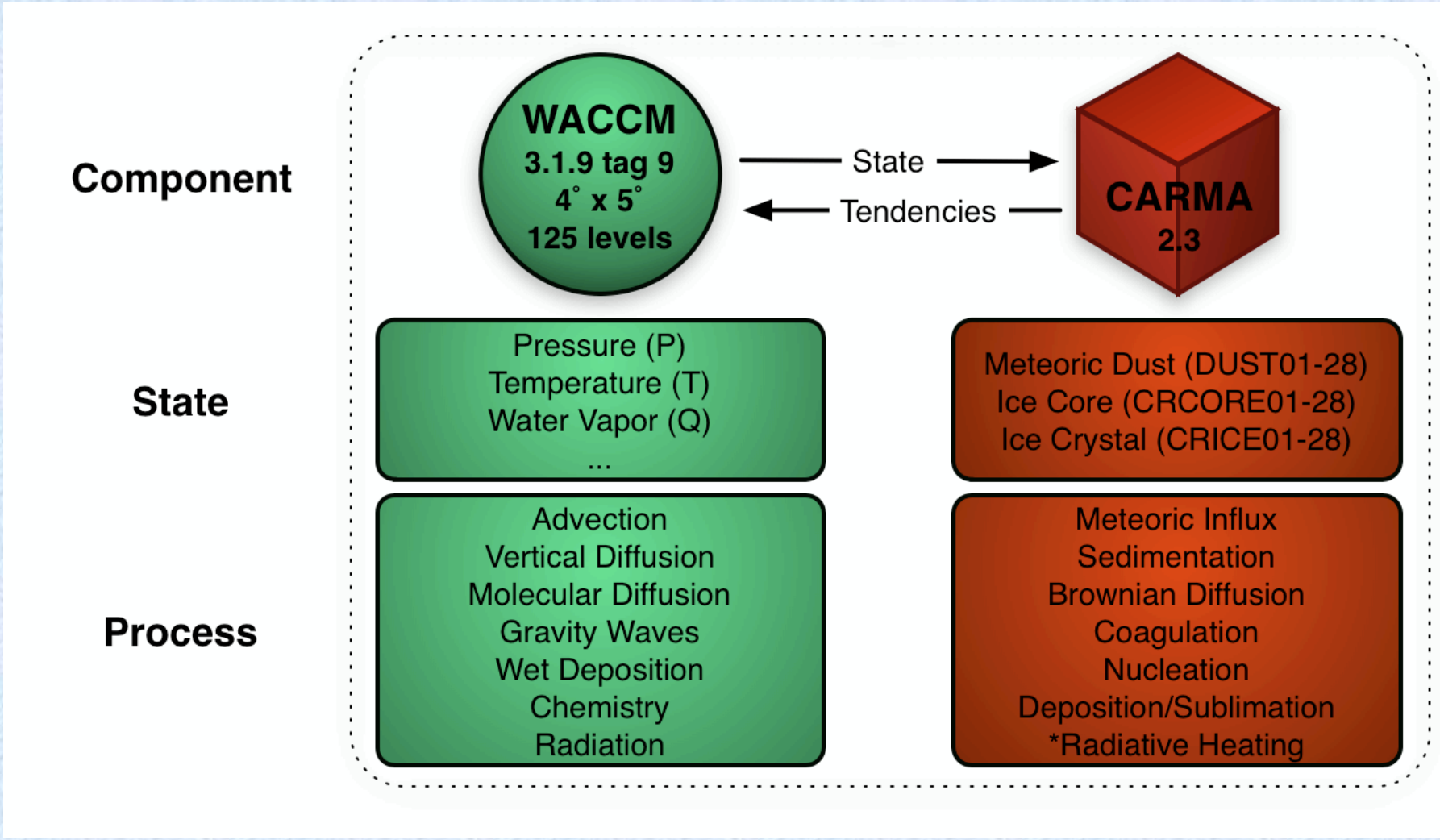
National Center for Atmospheric Research
Joan Alexander
Colorado Research Associates
Eric Jensen
NASA Ames Research Center
Brian Toon
University of Colorado
Mark Hervig
GATS, Inc.

WACCM Working Group Meeting
February 22, 2010





WACCM/CARMA

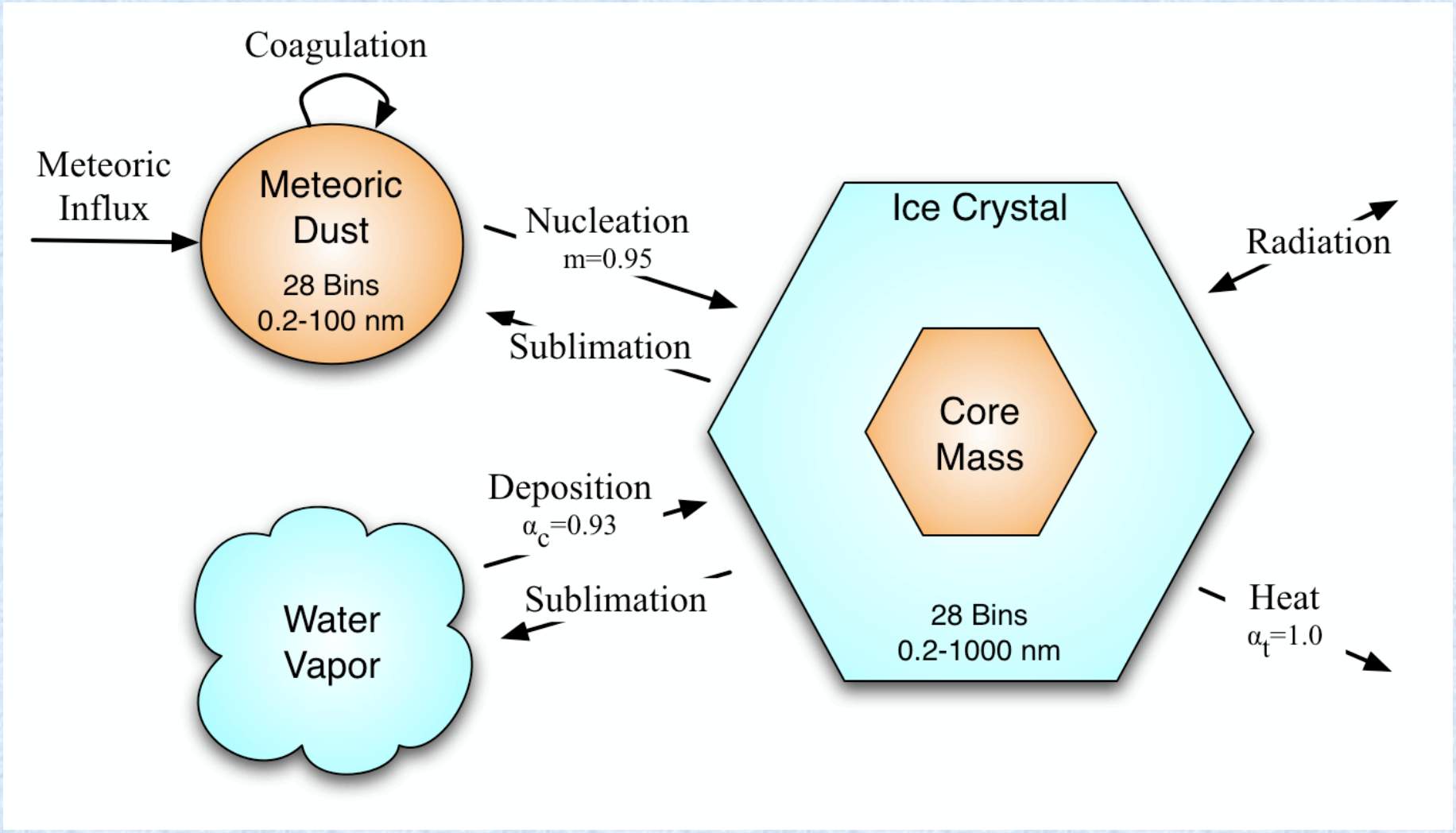

Component
State
Process
WACCM
3.1.9 tag 9
4˚ x 5˚
125 levels
State
Tendencies
CARMA
2.3
Pressure (P)
Temperature (T)
Water Vapor (Q)
...
Meteoric Dust (DUST01-28)
Ice Core (CRCORE01-28)
Ice Crystal (CRICE01-28)
Advection
Vertical Diffusion
Molecular Diffusion
Gravity Waves
Wet Deposition
Chemistry
Radiation
Meteoric Influx
Sedimentation
Brownian Diffusion
Coagulation
Nucleation
Deposition/Sublimation
*Radiative Heating

CARMA

Community Aerosol and Radiation Model for Atmospheres

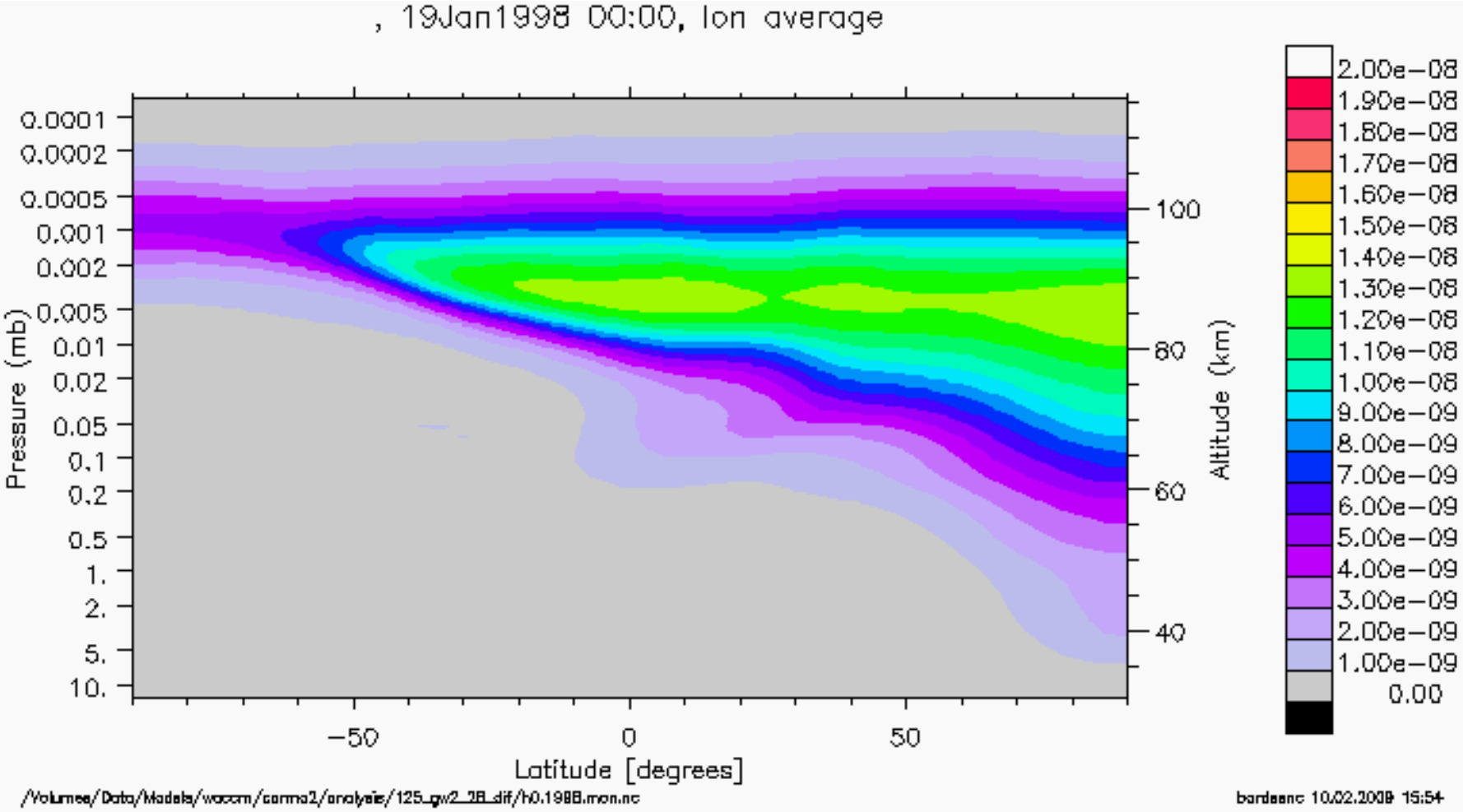
- *Turco et al.* [1979], *Toon et al.* [1988], Jacobson et al. [1994], …
- Sectional (Bin) Microphysics
- Flexible and Extensible
  - Sedimentation
  - Coagulation
  - Nucleation
  - Growth & Evaporation
  - Brownian Diffusion
  - Wet & Dry Deposition
  - Particle Swelling
  - Optical Properties (Mie)

WACCM/CARMA PMC Microphysical Model



Meteoric Dust Distribution

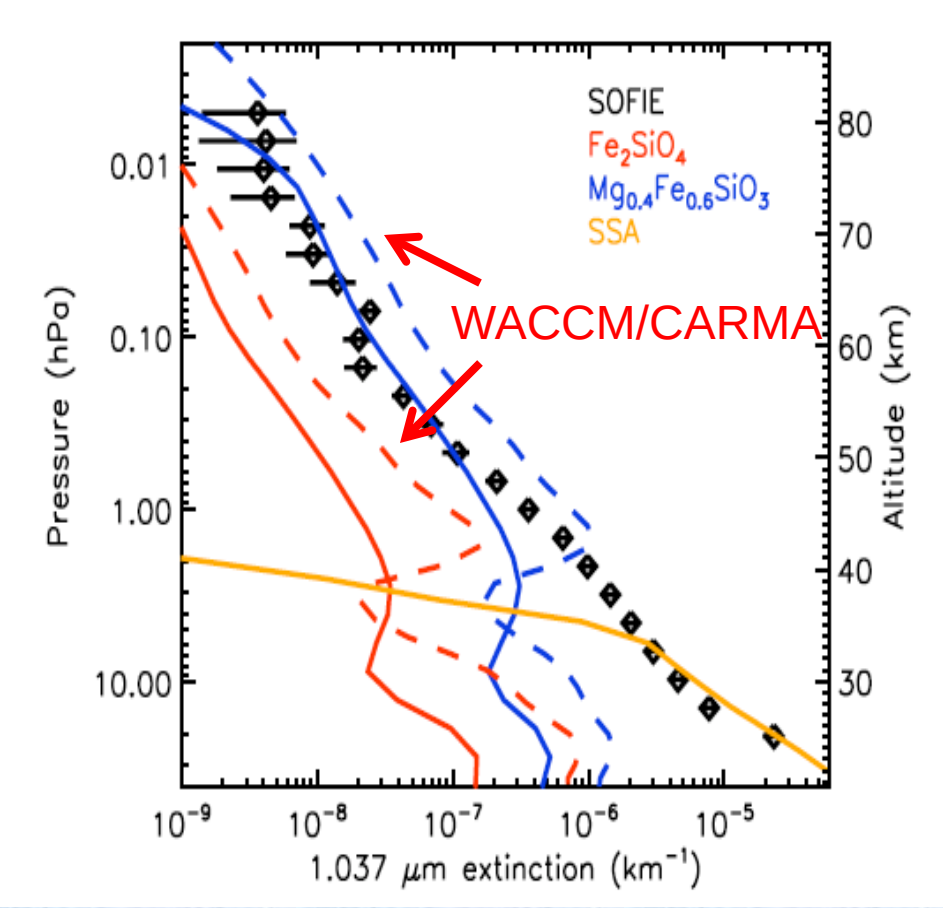
Dust MMR



[Bardeen et al., 2008]

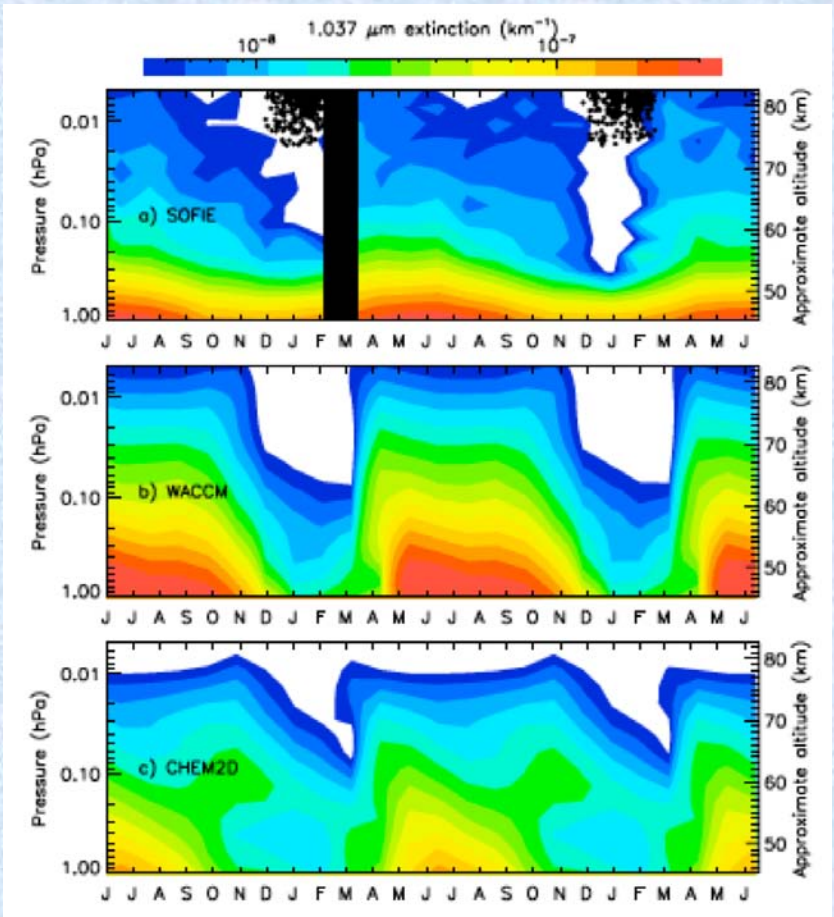
WACCM/CARMA & SOFIE : Dust

Vertical Profile, 65.2S



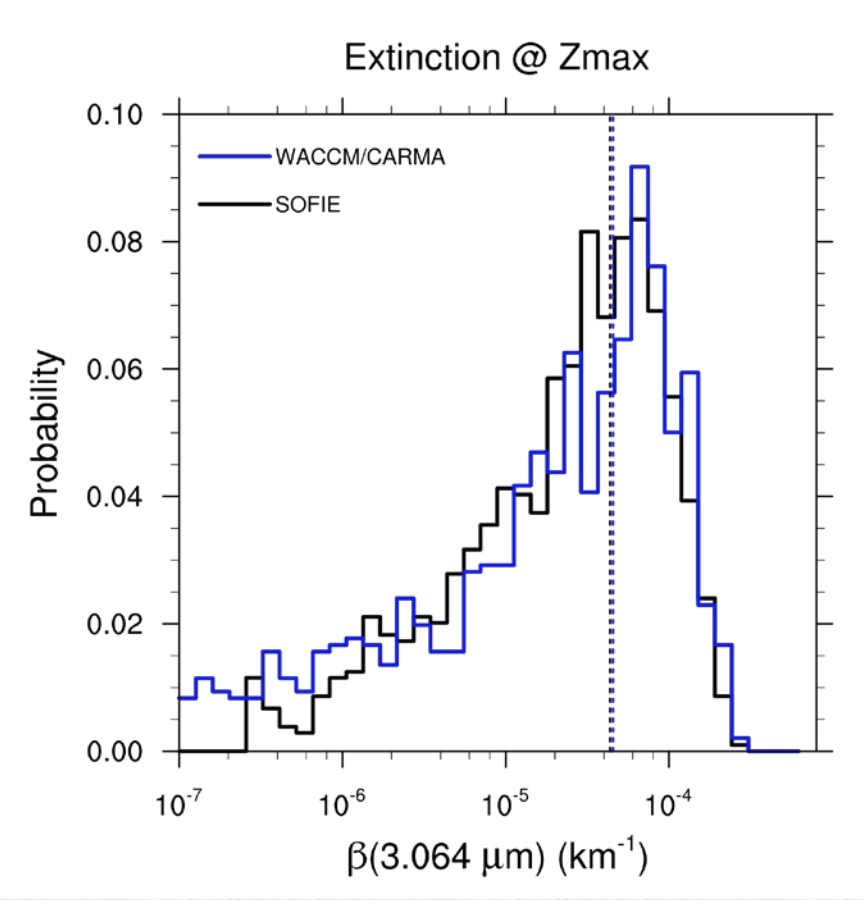
[Hervig et al., 2009]

SH Seasonal Cycle



[Hervig et al., 2009]

WACCM/CARMA & SOFIE : PMC



Summary

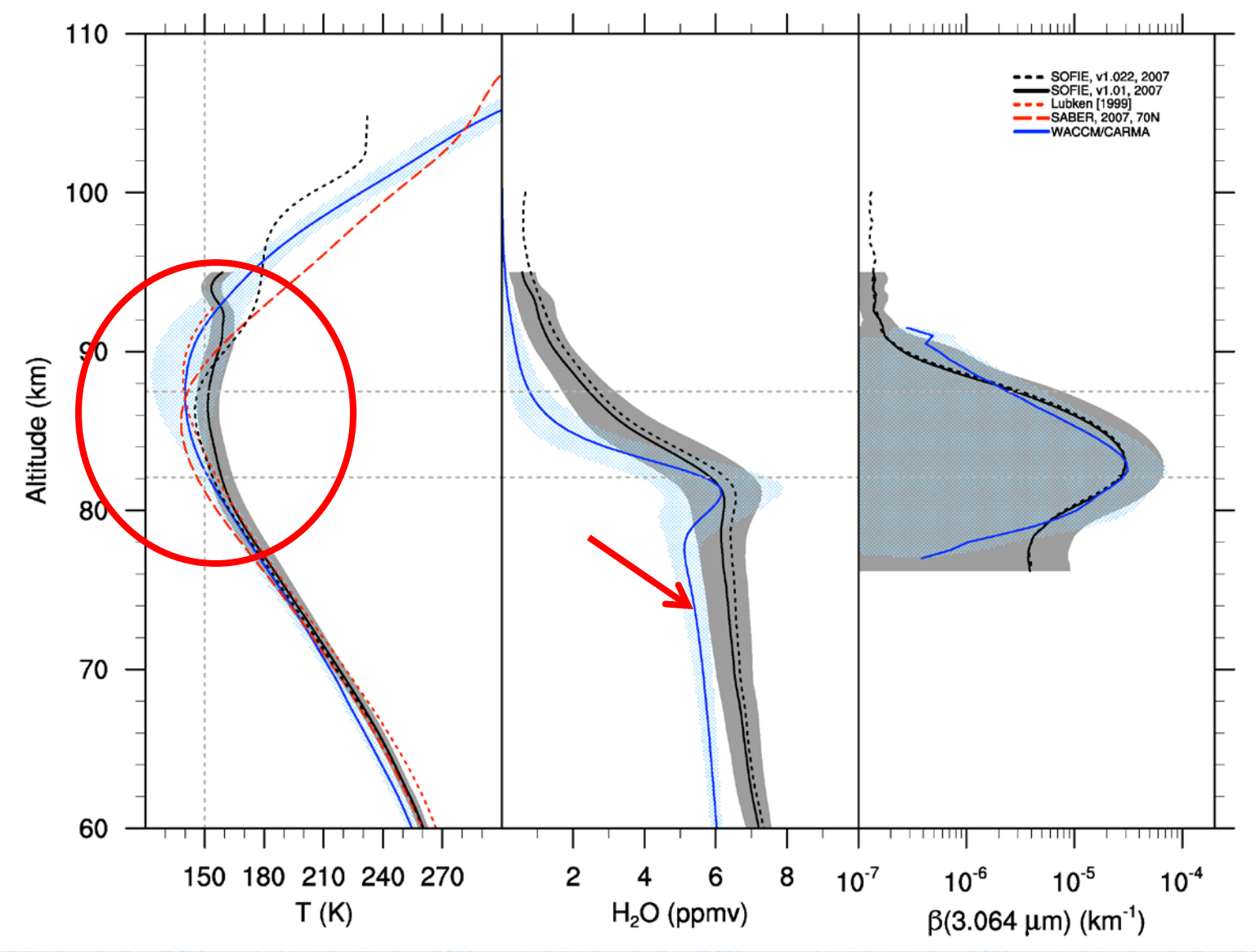
	SOFIE v1.01		WACCM/CARMA	
Events	1432		1432	
Clouds	1130	78.9%	959	66.9%
Zmax < 79 km	88	6.2%	0	0.00%

Seasonal Mean

	Units	SOFIE	WACCM	Difference
Height	km	83.53	83.26	-0.27 km
Base	km	80.16	80.78	0.62 km
Top	km	87.01	87.69	0.68 km
Thickness	km	6.85	6.92	0.96%
Column IWC	ug m^{-2}	36.65	30.32	-17.26%
B(3.064)	km^{-1}	4.36E-05	4.54E-05	4.18%
Re	nm	35.68	42.43	18.91%
Mass	ng m^{-3}	13.45	13.68	1.69%
Number	cm^{-3}	406.68	75.95	-81.33%
Water Vapor	ppmv	4.35	4.90	12.53%

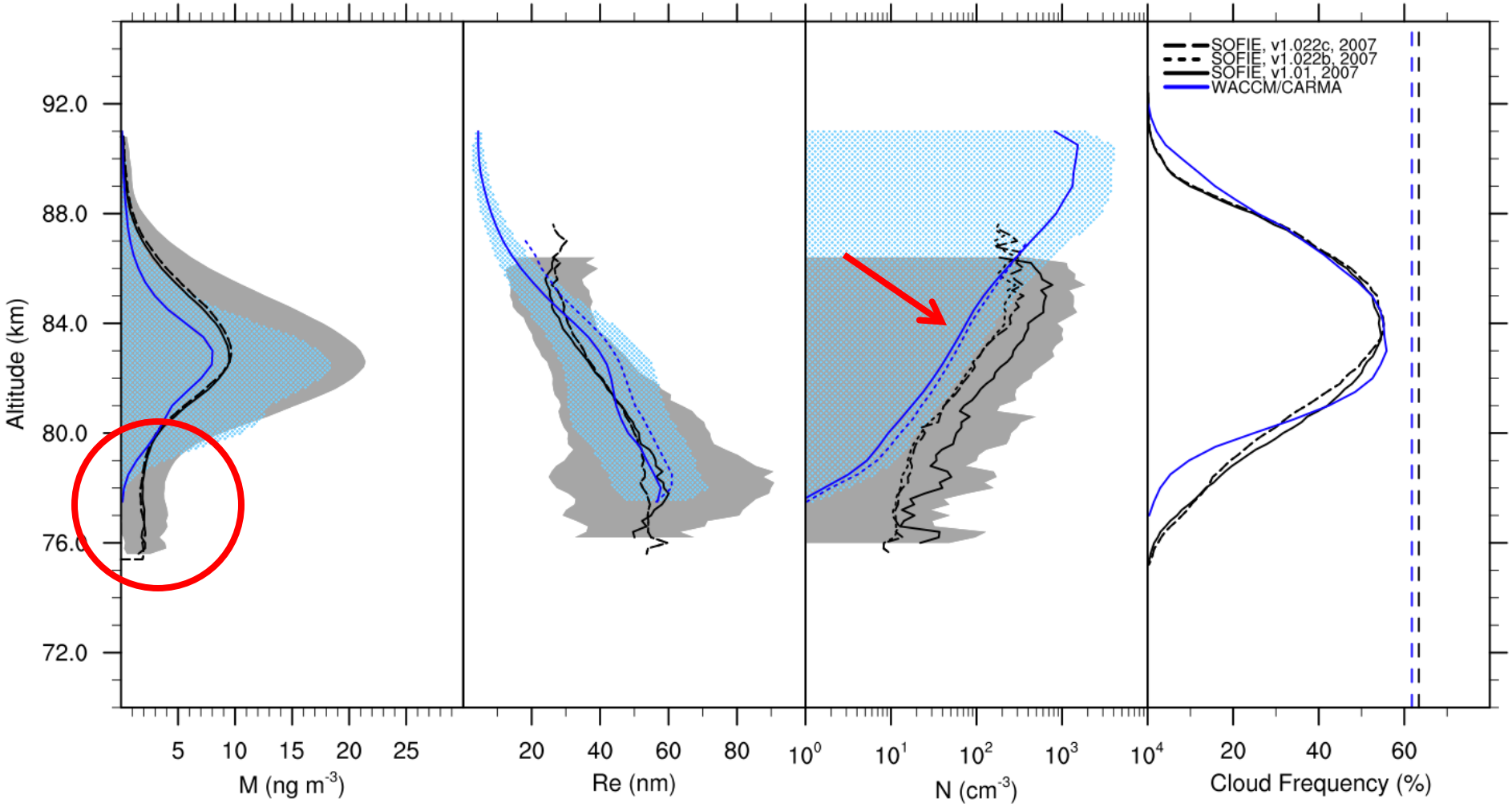
[Bardeen et al., JGR, In Press]

PMCs vs. SOFIE: T, H_2O, B



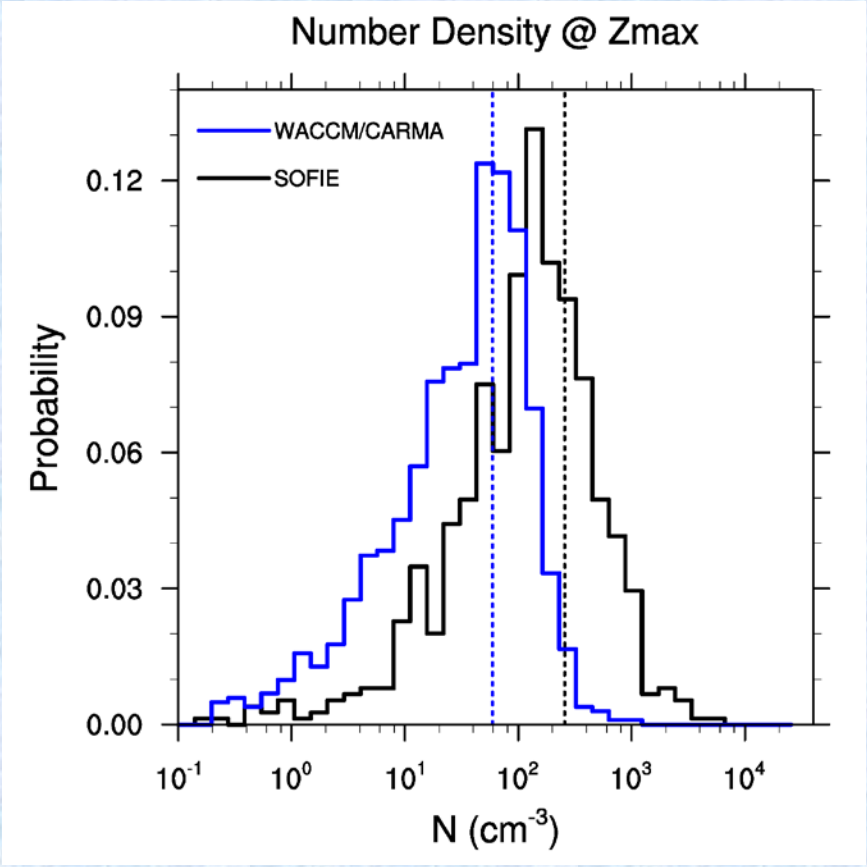
[Bardeen et al., JGR, In Press]

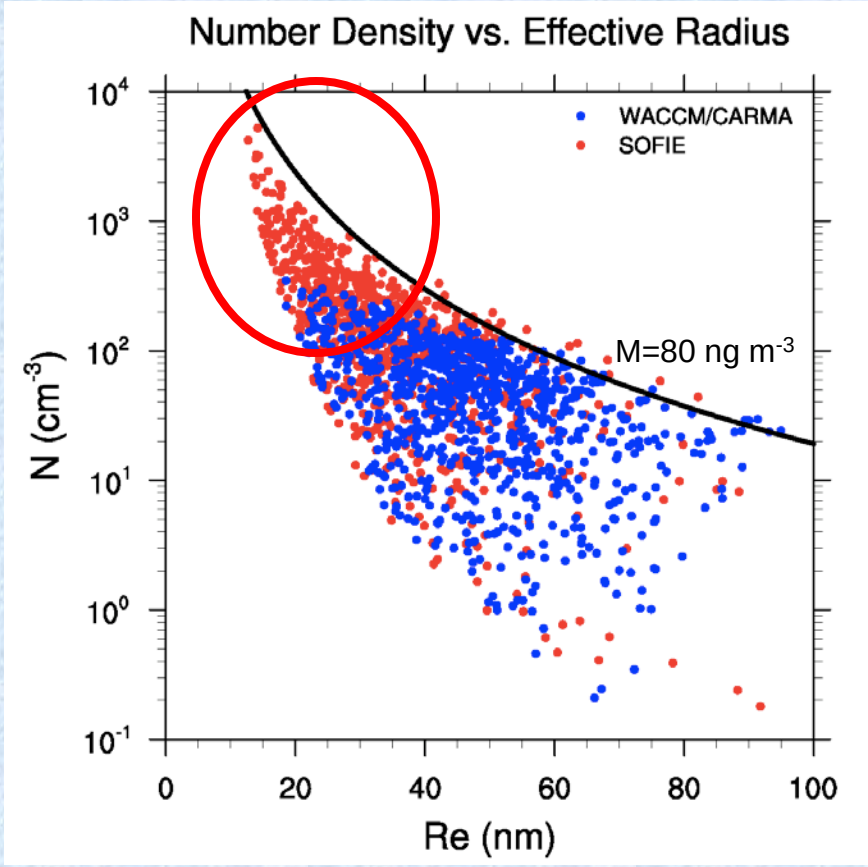
PMCs vs. SOFIE: M, Re, N



[Bardeen et al., JGR, In Press]

Number Density Details

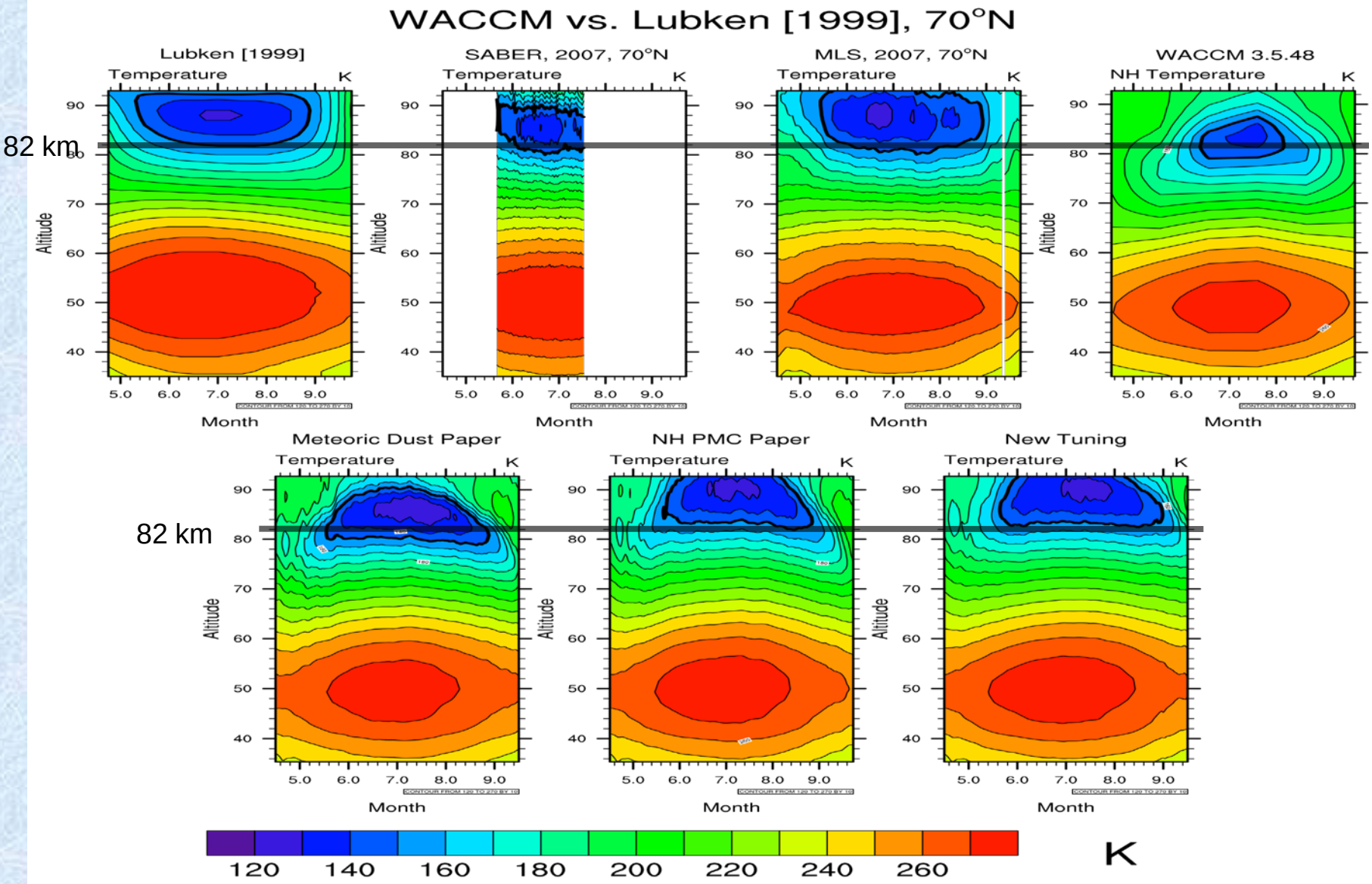




[Bardeen et al., JGR, In Press]

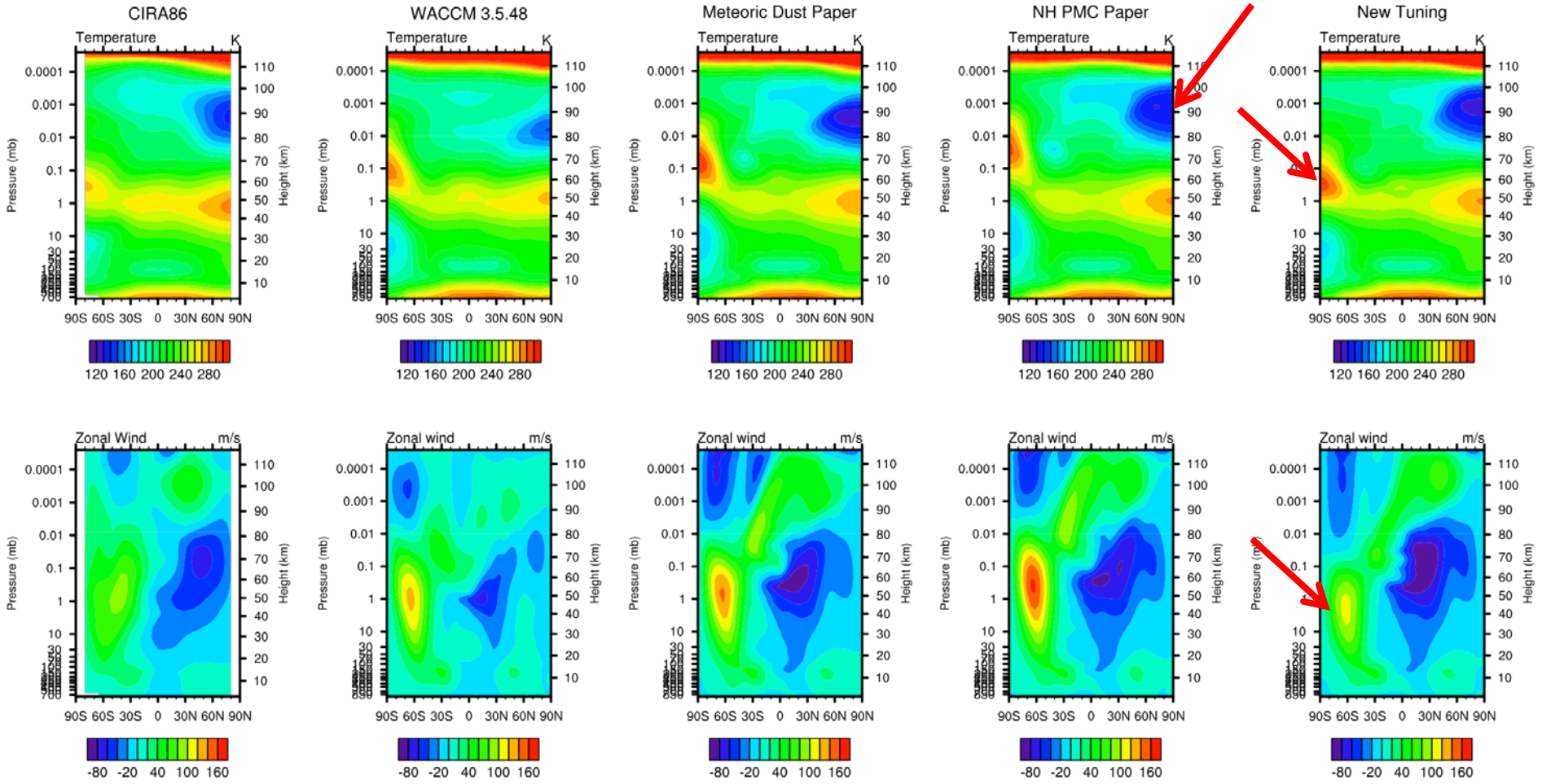
Gravity Wave Tuning

Summer Temperatures, 70˚N

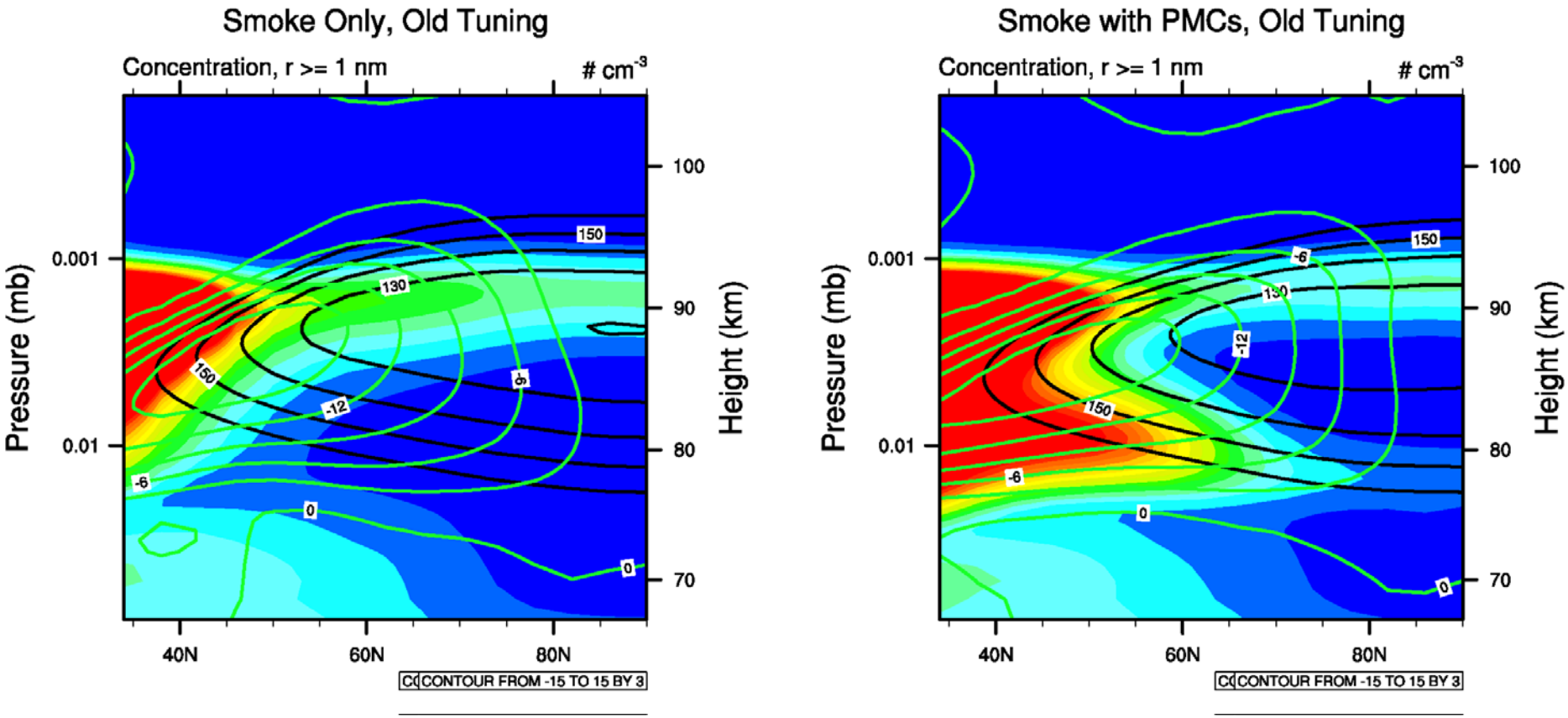


Gravity Wave Tuning

July Average

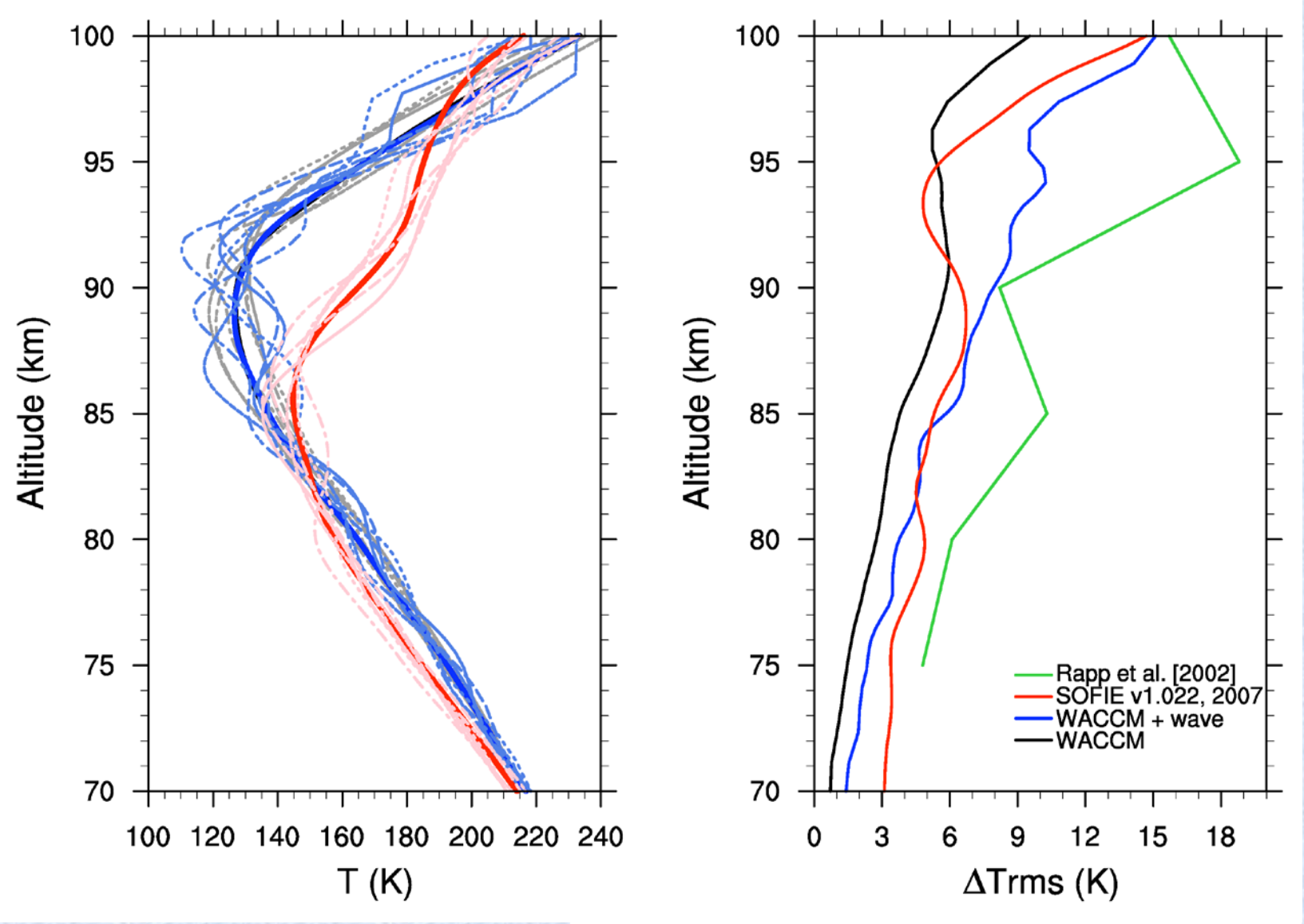


Meteoric Dust near the Summer Polar Mesopause



[Bardeen et al., JGR, In Press]

Subgrid Scale Gravity Waves



Rapp et al. [2002]

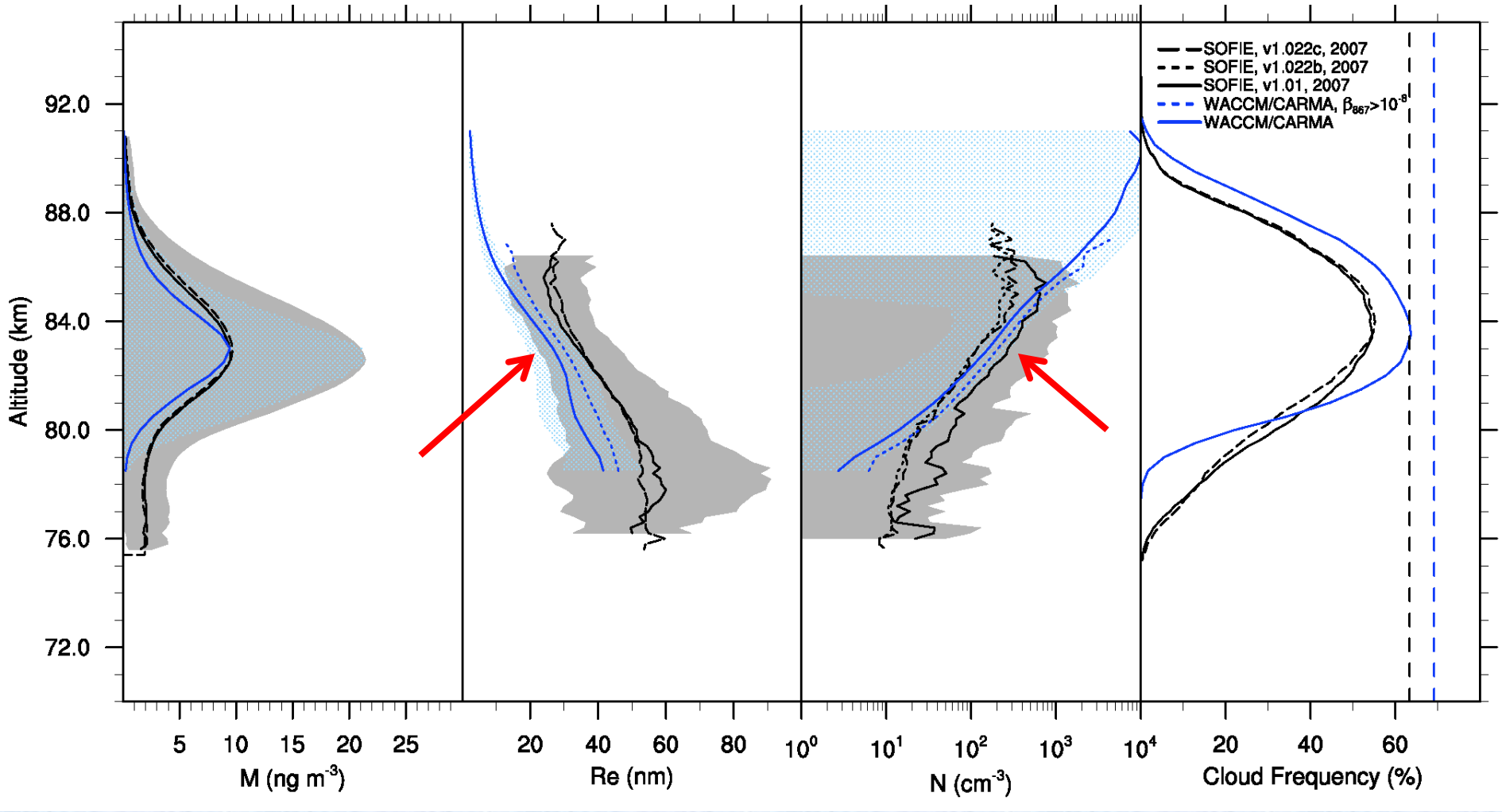
Gravity Wave Experiment
417 Minute Period

$$\Delta T = T_0(m)\sin(mz + \phi_m - \omega t)e^{z/D}$$

- $\Delta T = 0.5 * \Delta T_{Rapp}$
- Propagate waves in time with a period of 417 minutes, the average period from Rapp et al. [2002]
- Randomly pick m, Φ_m every 417 minutes in every column
- D = 14 km

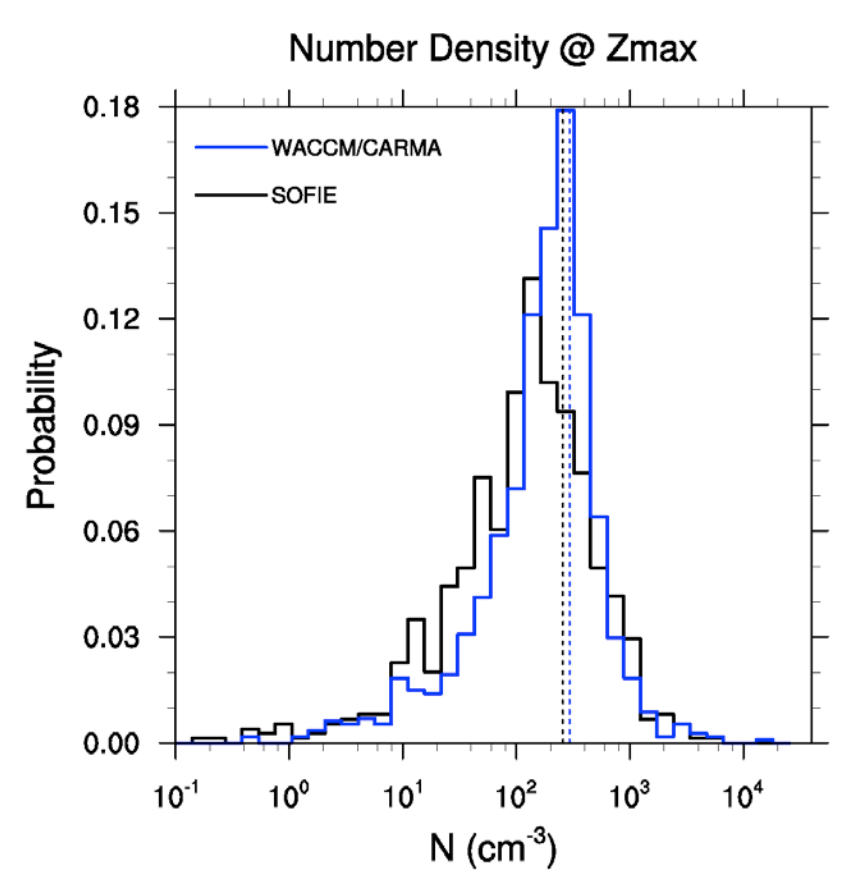
Periodic Waves, Period = 417 min

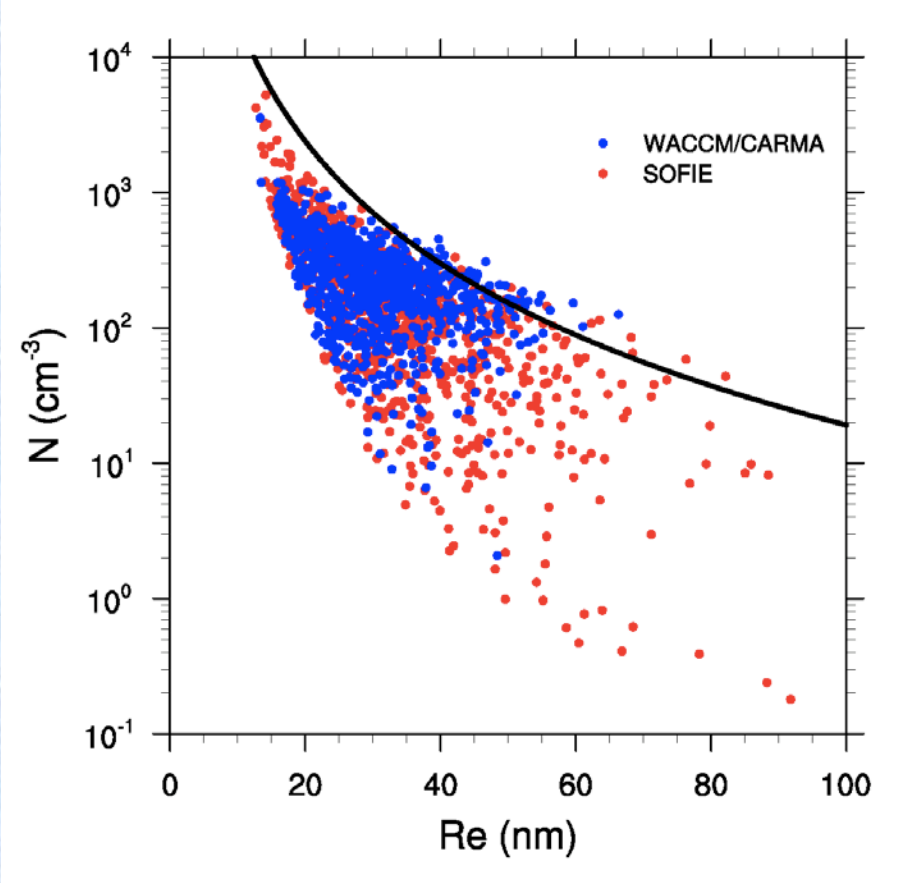
M, Re, N & Frequency



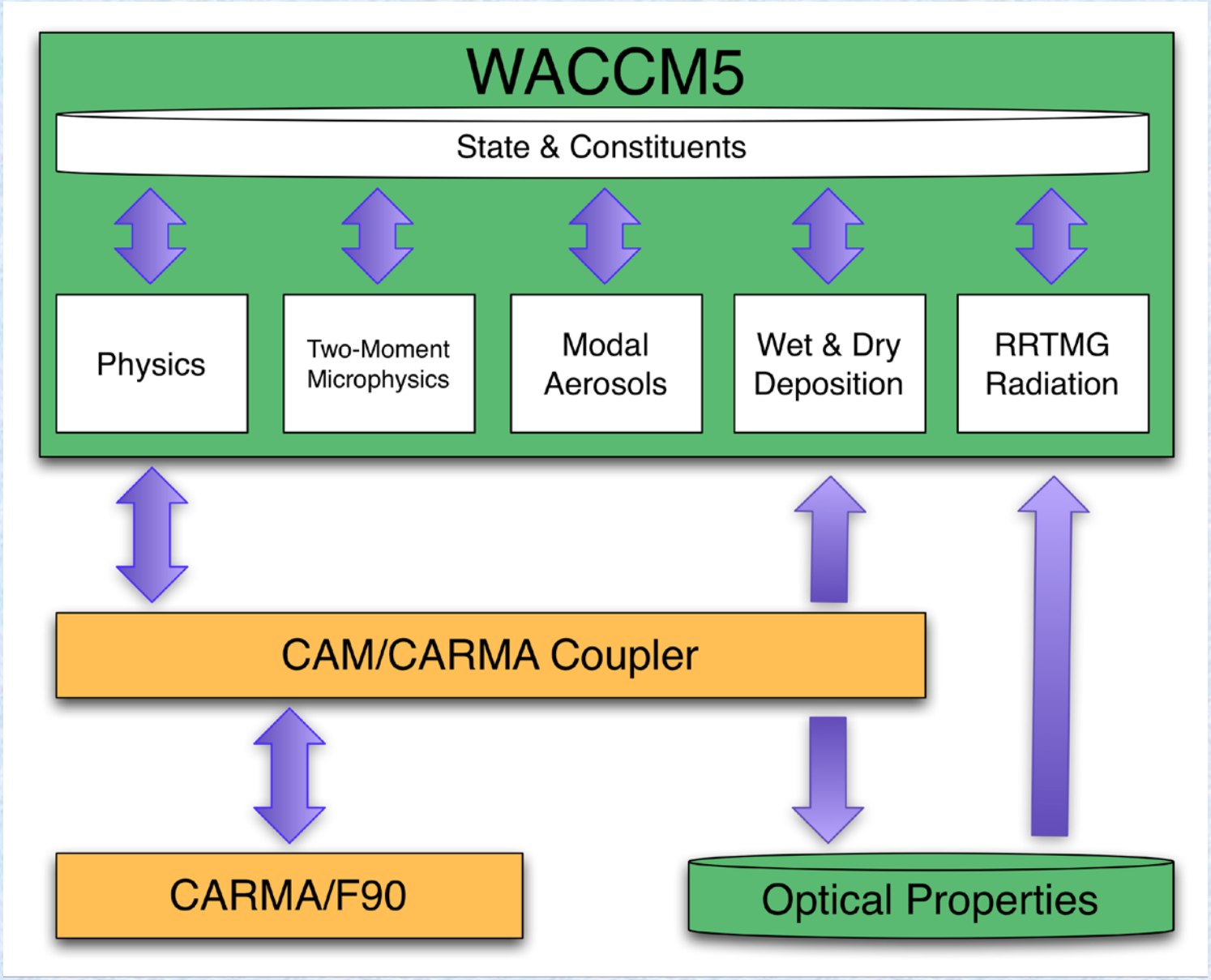
Periodic Waves, Period = 417 min

Number Density





WACCM5/CARMA



CARMA/F90 Enhancements

- **Software Engineering**
  - **Written in Fortran 90**
  - **Code Simplified (Single Column Only)**
  - **Integrated into CAM Build Structure**
  - **Supports OPEN/MP & Hybrid (Thread Safe)**
  - **Same Answers Across Restarts & Decomposition**
  - **Dynamic Allocation of CARMA Variables**
  - **Includes a Configuration Interface**
  - **Uses CAM Constants**

- **Physics**
  - **Several CARMA 2.3 Bugs Fixed**
  - **Improved Substepping Performance (Retry)**
  - **Prognostic & Diagnostic Groups**
  - **Particle Swelling (Gerber, 1985; Fitzgerald, 1975)**
  - **Integrated with CAM Radiation Code (Mie, RRTMG)**

CARMA Projects

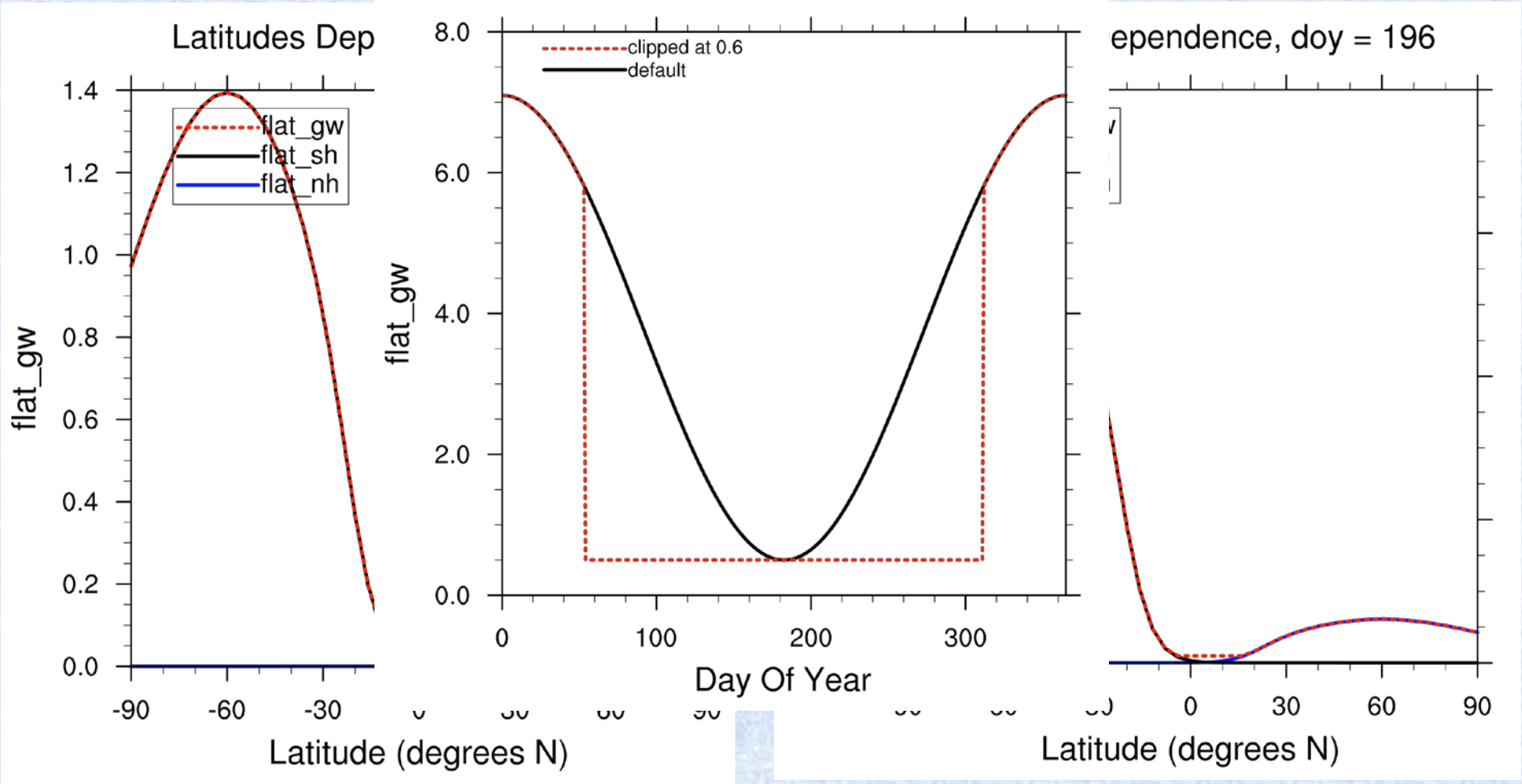
- **CAM/CARMA**
  - TTL Cirrus (Bardeen)
  - Dust (Su)
  - Sea Salt (Fan)
  - Smoke (Smith)

- **WACCM/CARMA**
  - Meteoric Smoke Particles (Bardeen)
  - Stratospheric Soot Particles (Mills)
  - Polar Mesospheric Clouds (Bardeen, Mills, Benze)
  - Sulfate Aerosols (Mills, English)
  - Early Earth Haze (Wolf)
  - Polar Stratospheric Clouds (Zhu)
  - Meteor Impact (Bardeen, Mills)

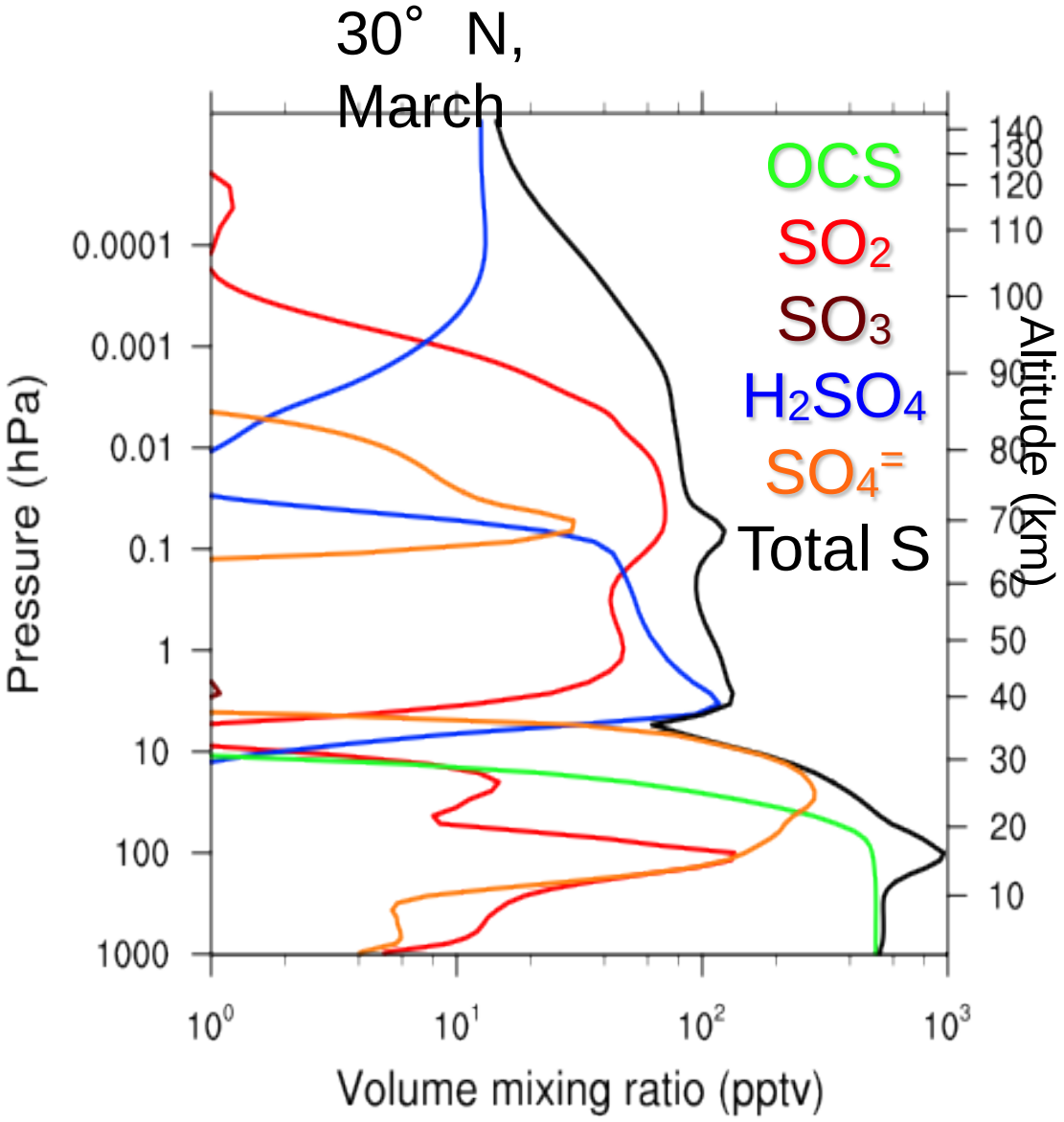
Gravity Wave Tuning

Seasonality of the Source Strength

Old, taubg ubgnd = 1.5



The Viability of Sulfates in the Mesosphere



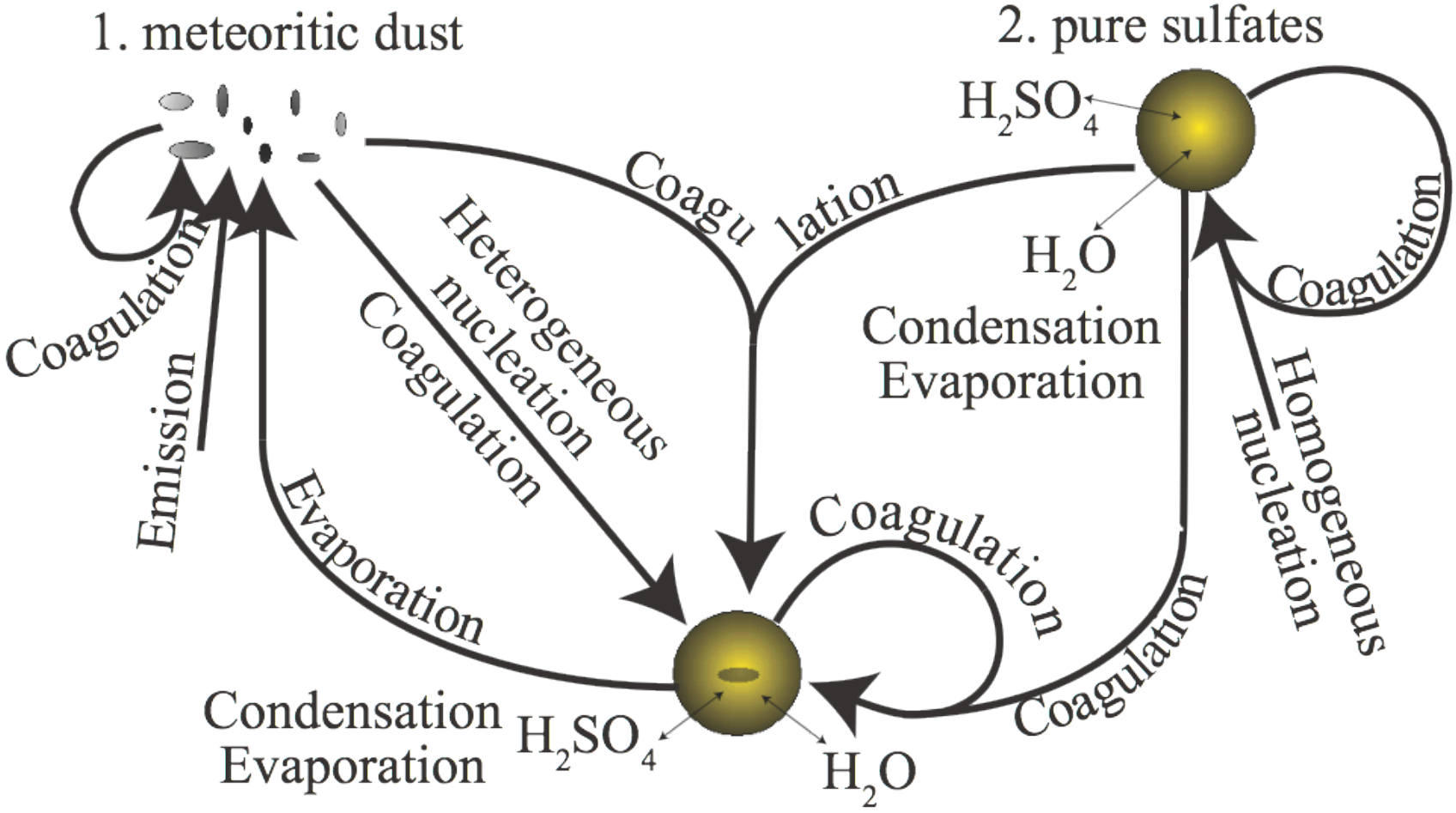
In the PMC region,
χ_{H2SO4} ~ 1 pptv
χ_{H2O} ~ 4 ppmv

Flux rates to a 1-nm-radius aerosol:

$\sqrt{}_{H2SO4}$ ~ 5×10^{-6} molec/s
➥ > 2 days/molec

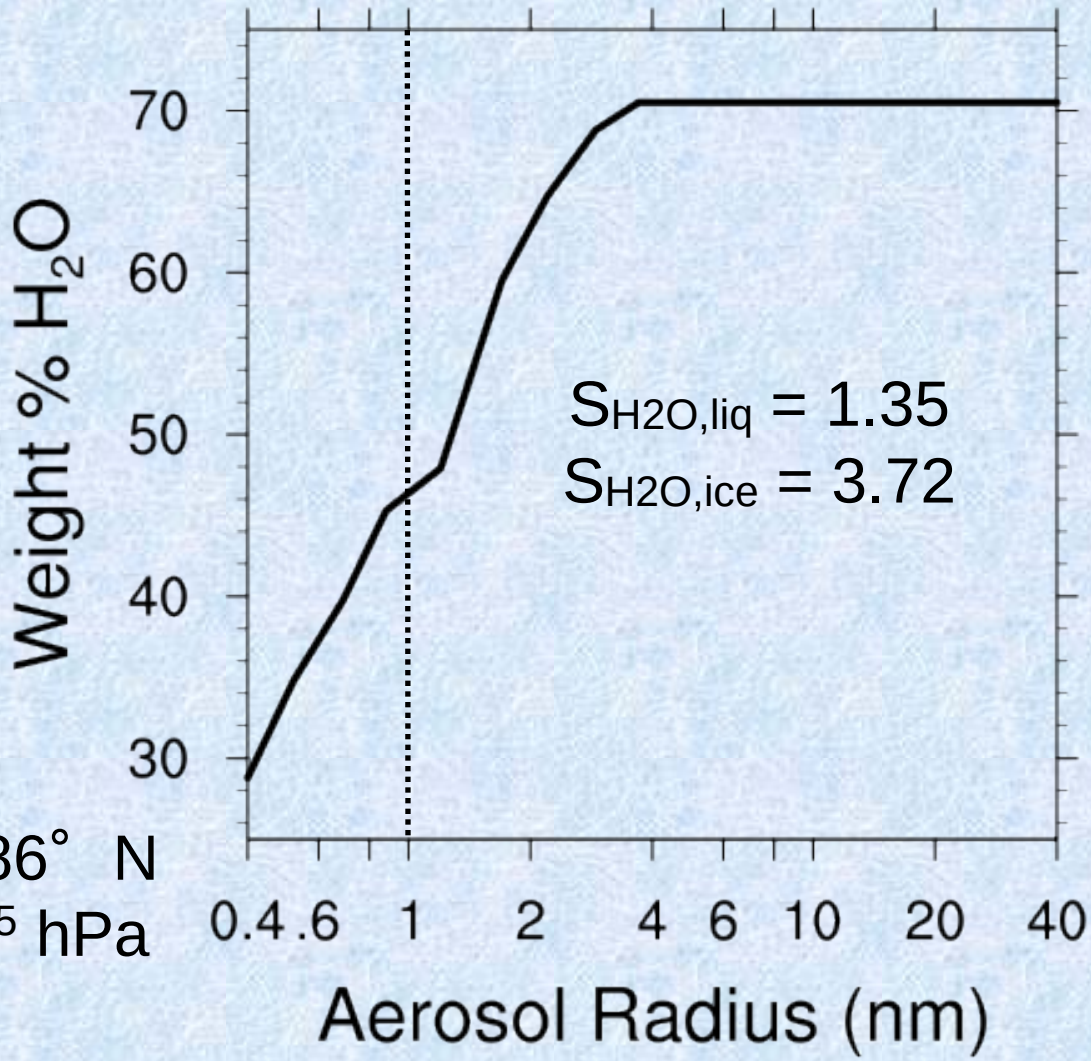
$\sqrt{}_{H2O}$ ~ 5 molec/s

WACCM/CARMA dust-sulfate microphysics



The Kelvin Effect for Water

The model currently limits the water composition of aerosols to no more than 70.5% by weight, due to the lack of vapor pressure data for more dilute solutions.



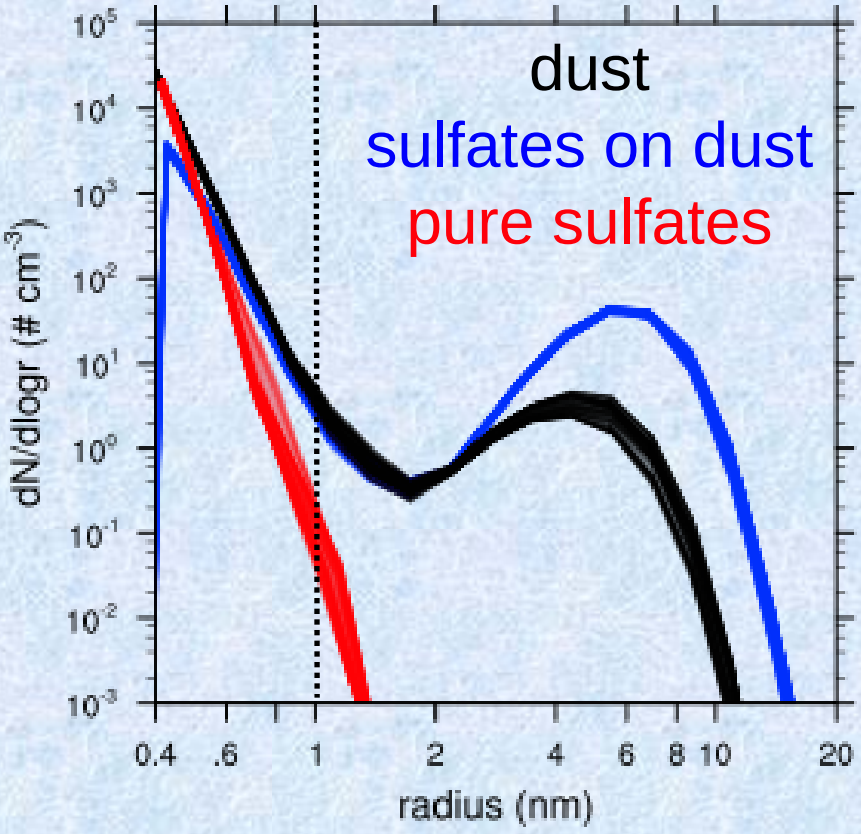
July 1, 0.005 hPa, 86° N

$P(H_2O) = 2.10 \times 10^{-5}$ hPa

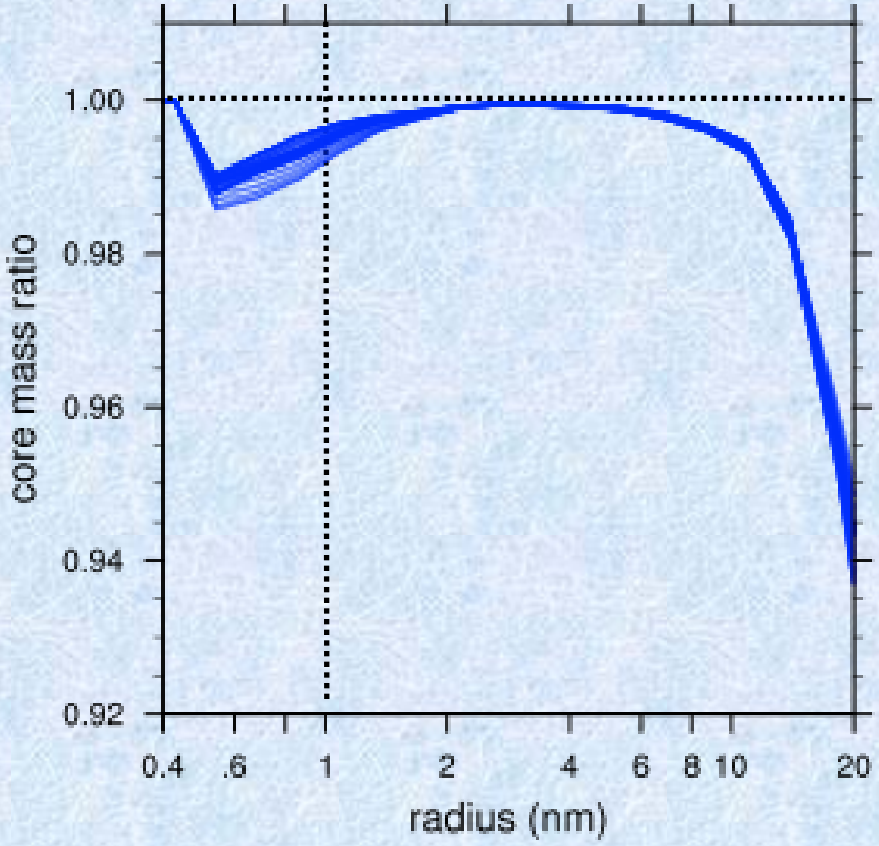
T = 142 K

Post-Pinatubo, June 1, 1992, 86° N, 83 km

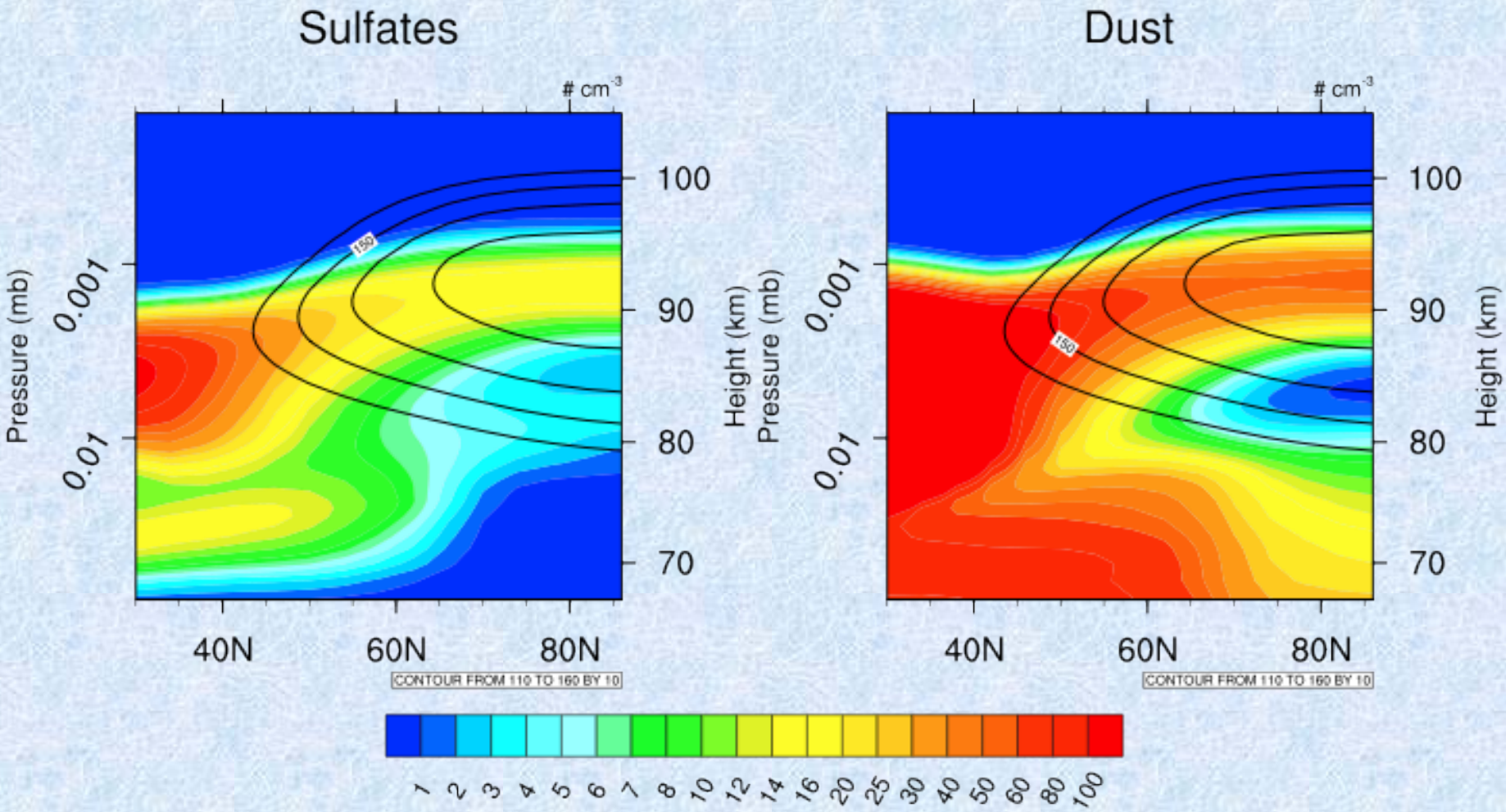
size distribution



core mass ratio



July 1992 Average #/cm^3, r>1 nm



July 1992 Average #/cm^3, r>0.5 nm