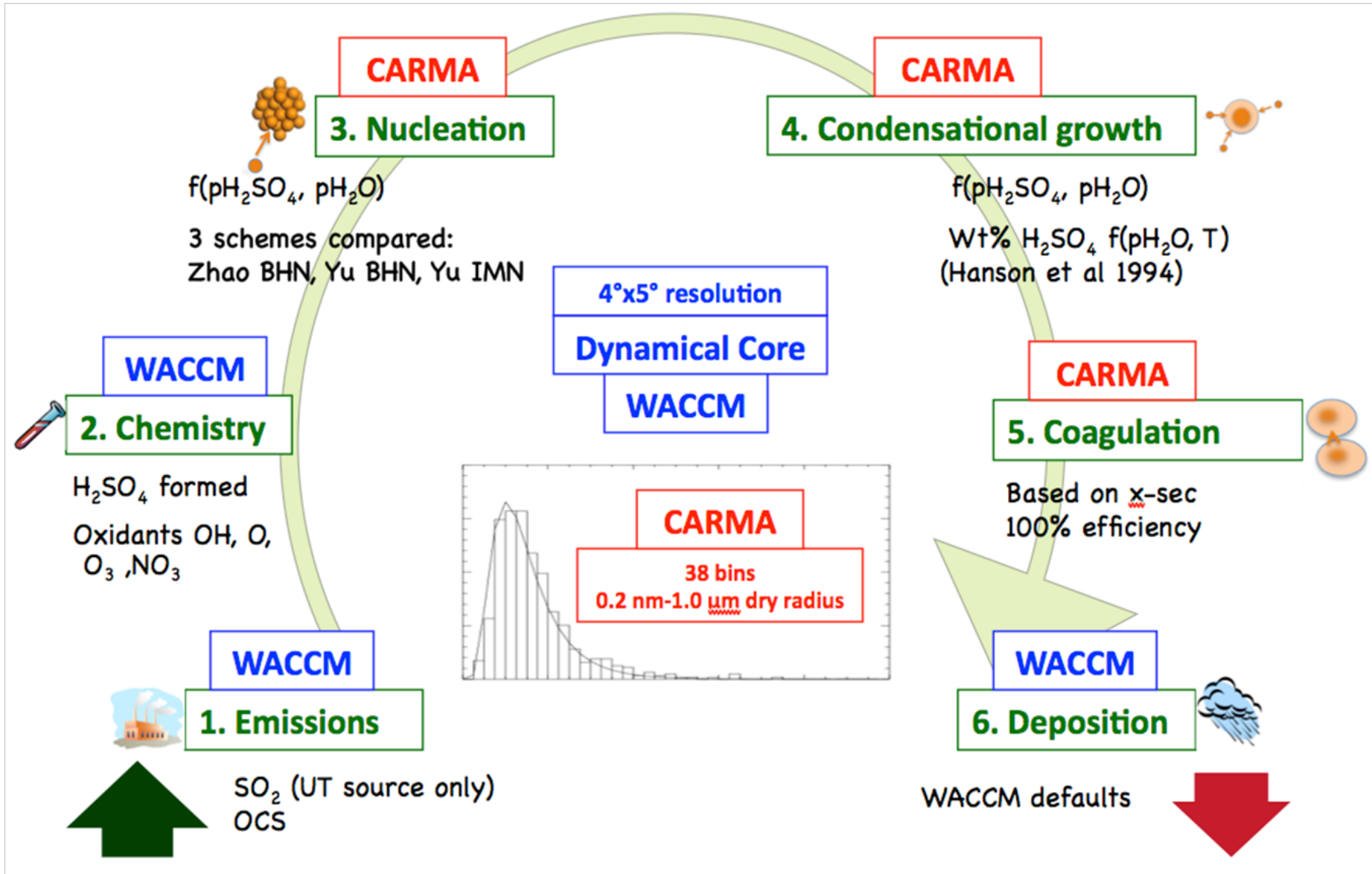


Sulfate Aerosol Nucleation in the UTLS using WACCM/CARMA

**Jason English
CCSM Chemistry-Climate Meeting
June 16, 2009**

Modeling Approach



2 year simulations; 2nd year averaged

Study Design

Simulation	Description
Zhao BHN	Critical Gibbs free energy calculated via % H_2SO_4 and cluster volume (<i>Zhao and Turco 1995</i>)
Yu BHN	Lookup tables based on quasi-unary nucleation of H_2SO_4 in equilibrium w/ H_2O vapor (<i>Yu 2008-1</i>)
Yu IMN	Lookup tables based on Yu BHN plus IMN, 10 ion-pairs/ cm^3 (<i>Yu 2008-2</i>)

BHN=Binary Homogeneous Nucleation of sulfuric acid-water
IMN=Ion-Mediated Nucleation of sulfuric acid-water

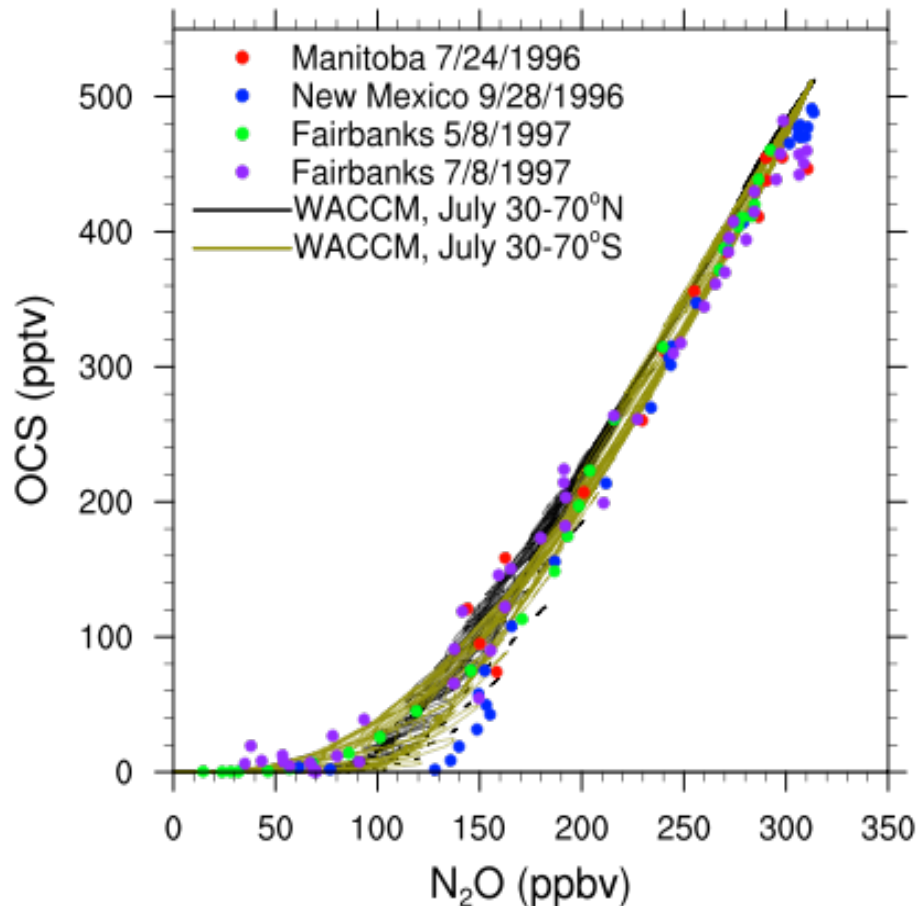
Sulfur Emissions

OCS emissions: 517 pptv in troposphere

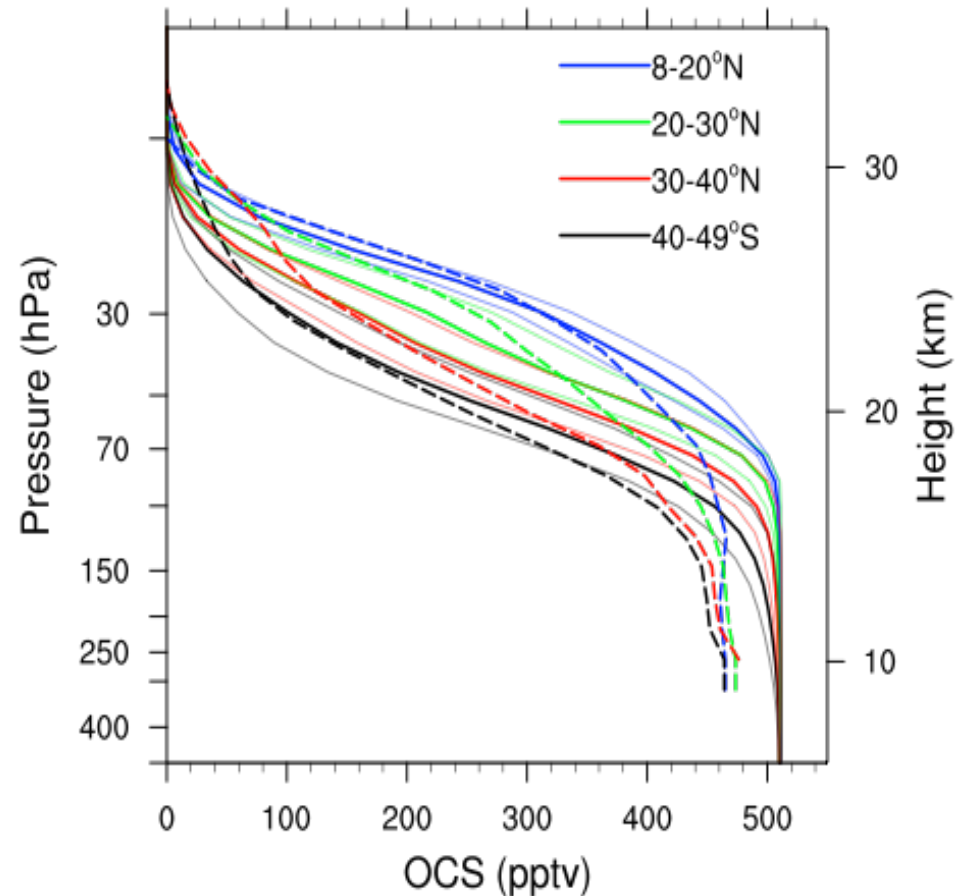
SO₂ emissions: 800 / cm^3/s at $<30^\circ$ lat >100 hPa,
no surface emissions

OCS good (need to refine trop conc)

WACCM vs. MkIV
balloon data (G. Toon)



WACCM (solid) vs.
SPARC report (dashed)



Courtesy of Mike Mills

SO₂ high in US/low in LS

2D Model

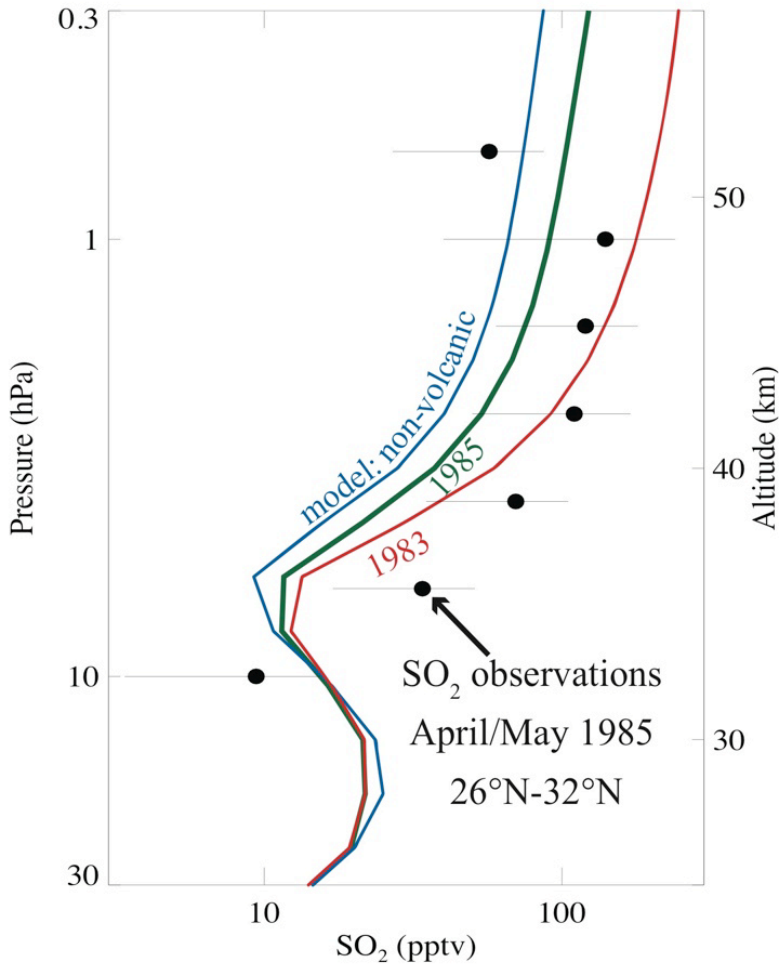
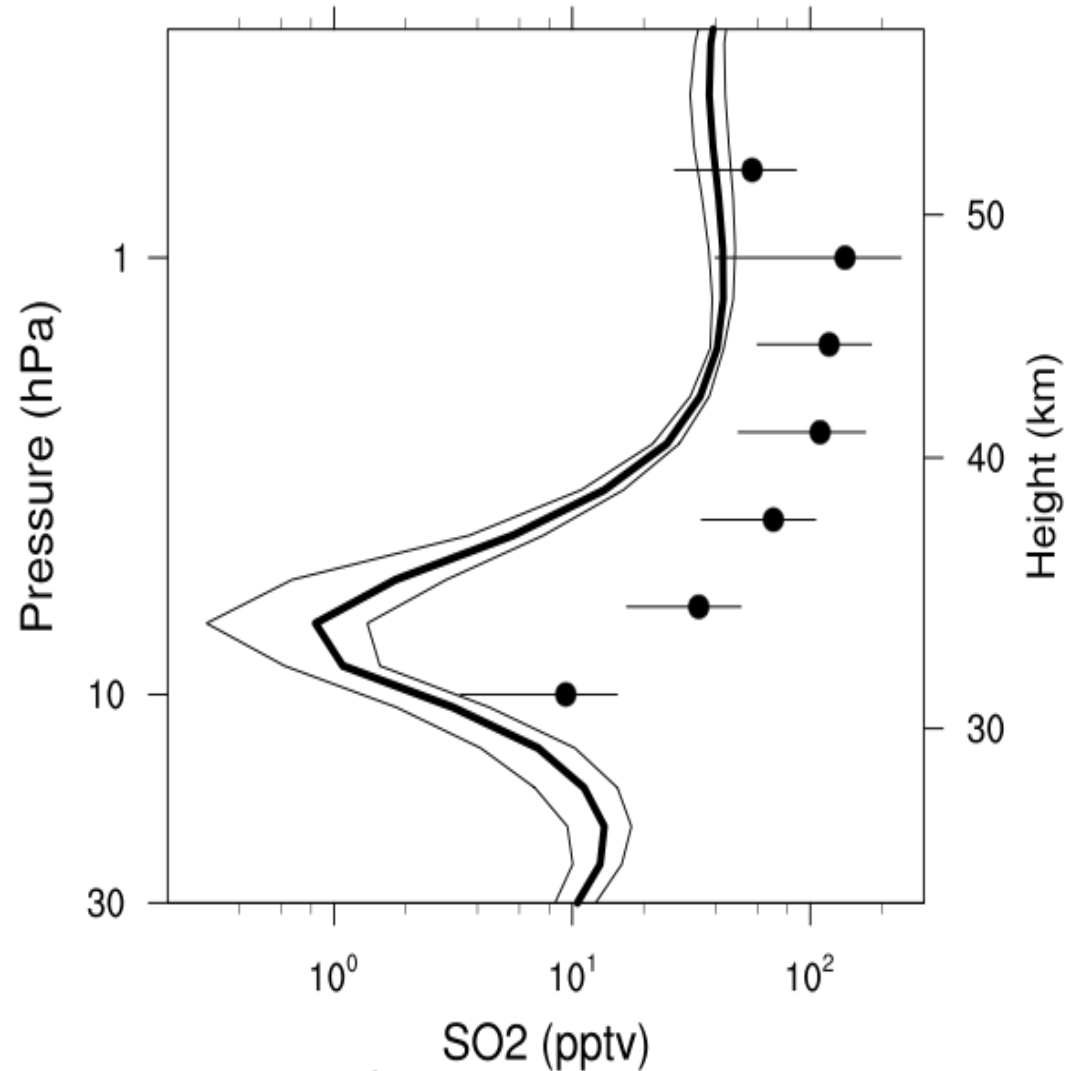
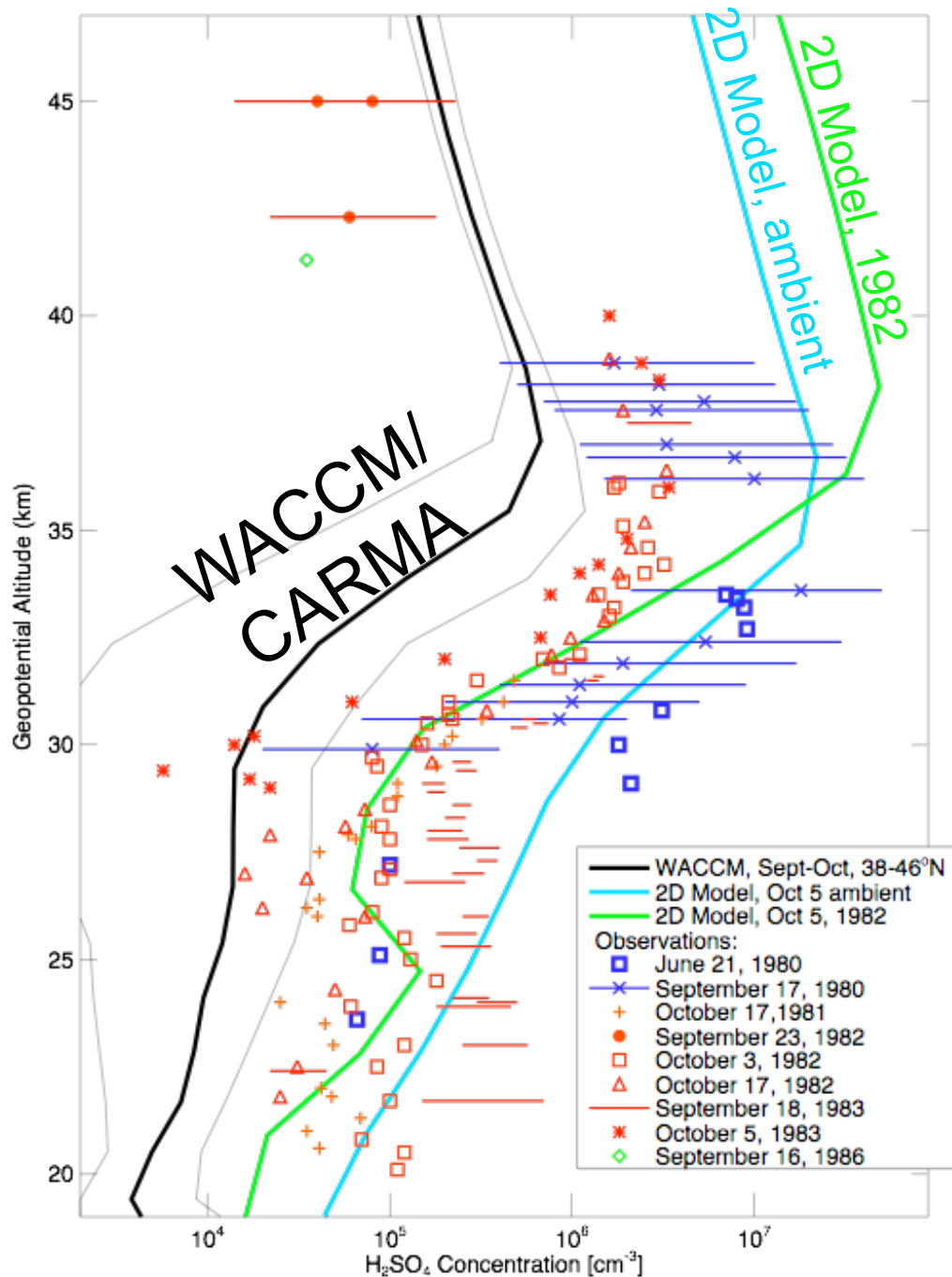


Figure 3 from Mills *et al.* [2005b]

WACCM, mesospheric tuning



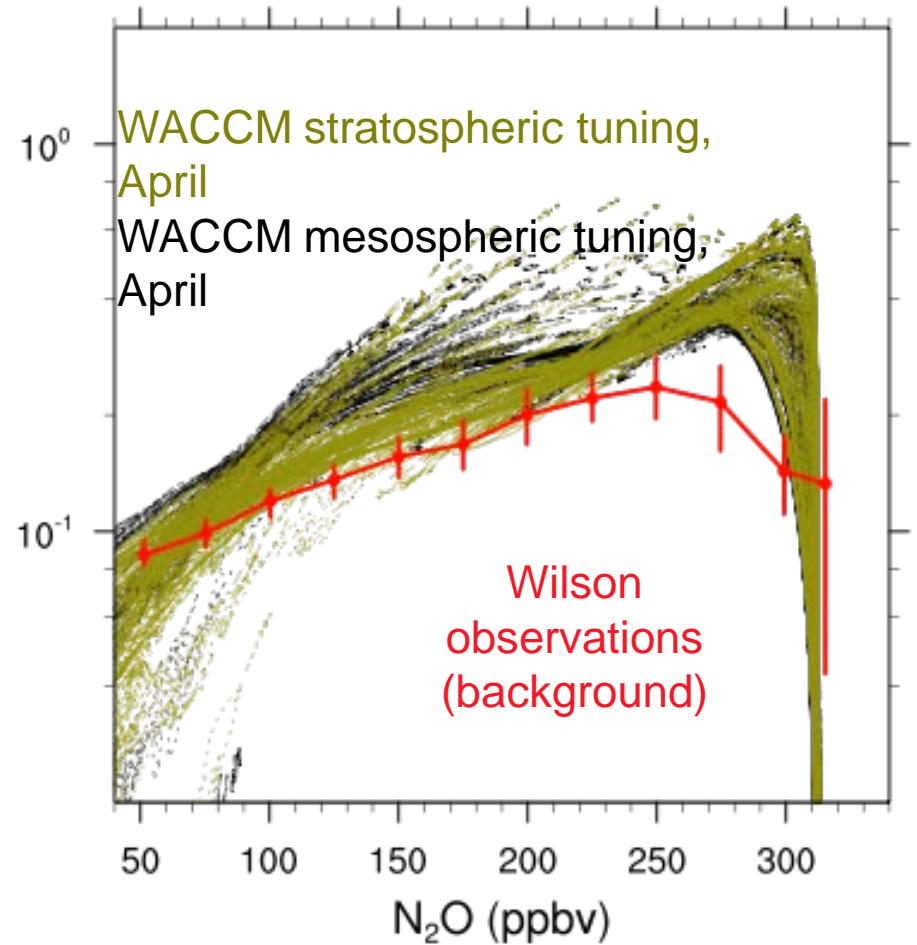
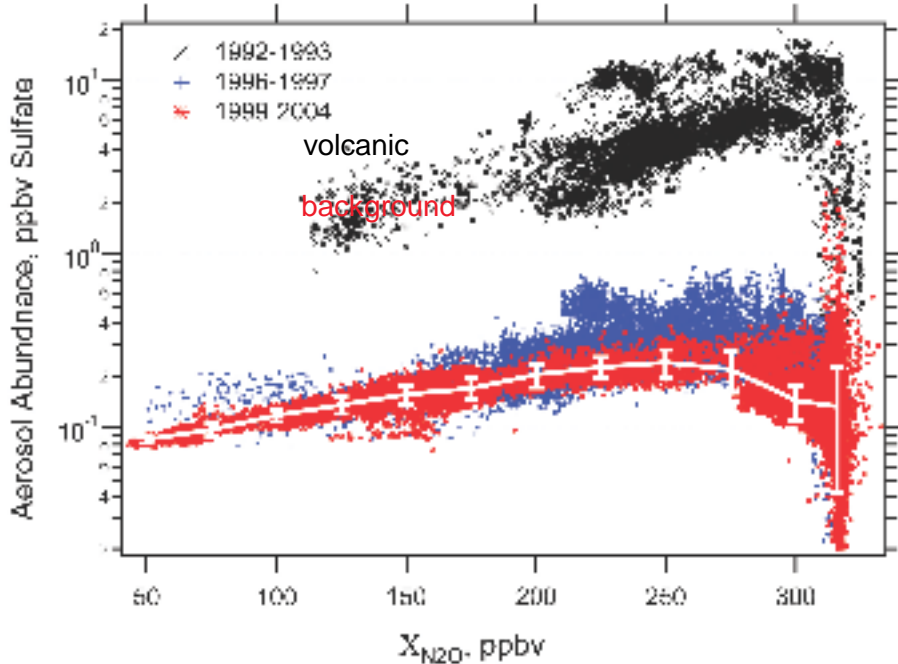
Courtesy of Mike Mills



H_2SO_4 too low
(excess sulfate
surface area
drawing it down)

Courtesy of Mike Mills

Sulfate vs. N₂O good except peak nucleation

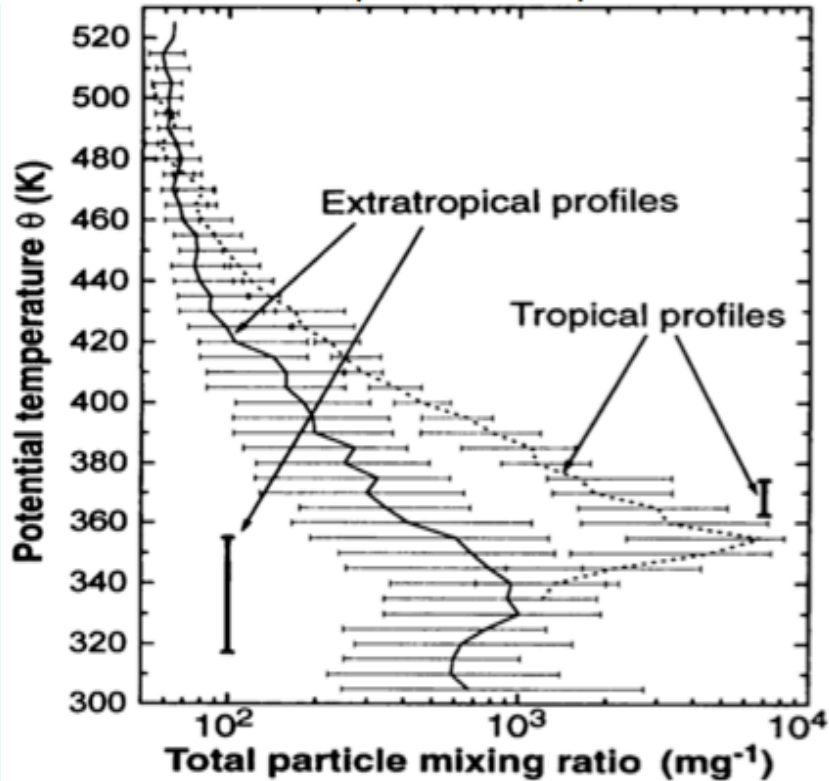


- Wilson et al. (ACP, 2008) aircraft observations

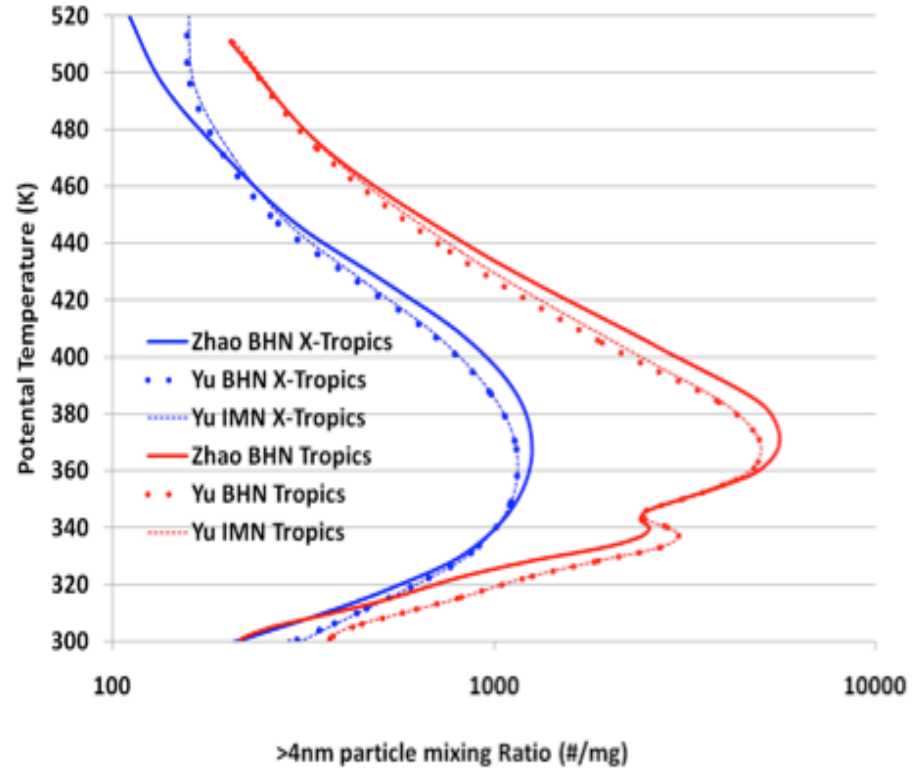
Courtesy of Mike Mills

Number Concentrations – Vert Profile

Obs. (Brock 1995)



Simulated Number Concentrations

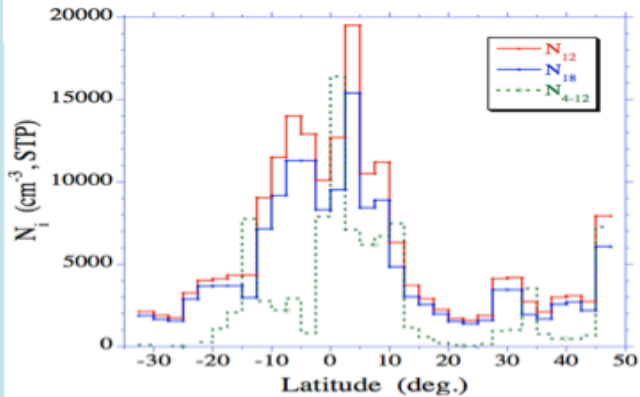


- Vertical profile of number concentrations matches observations well

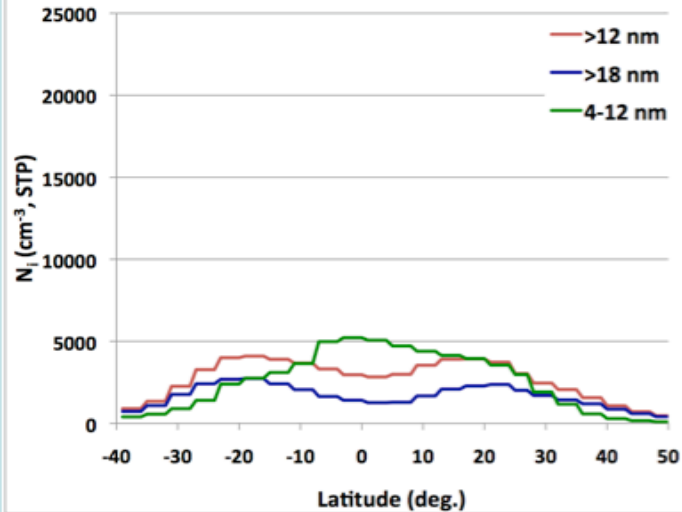
- Zhao BHN scheme predicts higher number in upper troposphere; lower in mid troposphere

Number Concentrations – Zonal Profile

Obs. (Heintzenberg, 2003)
CARIBIC 8.8-11km



Zhao BHN

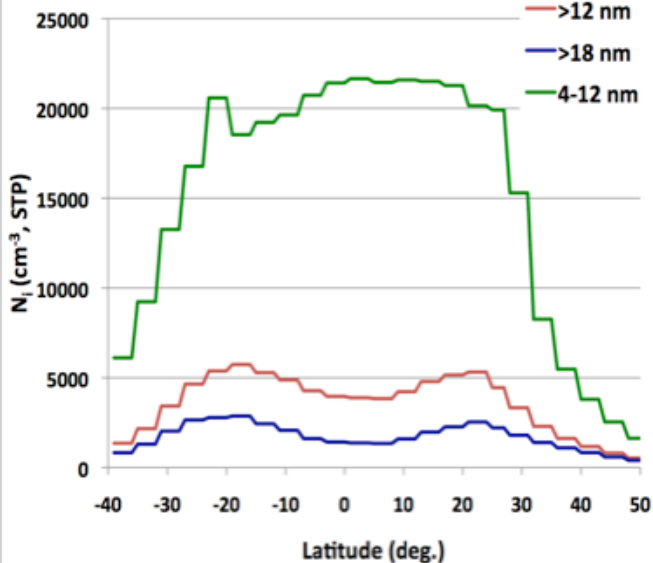


- Zhao BHN lower at this altitude

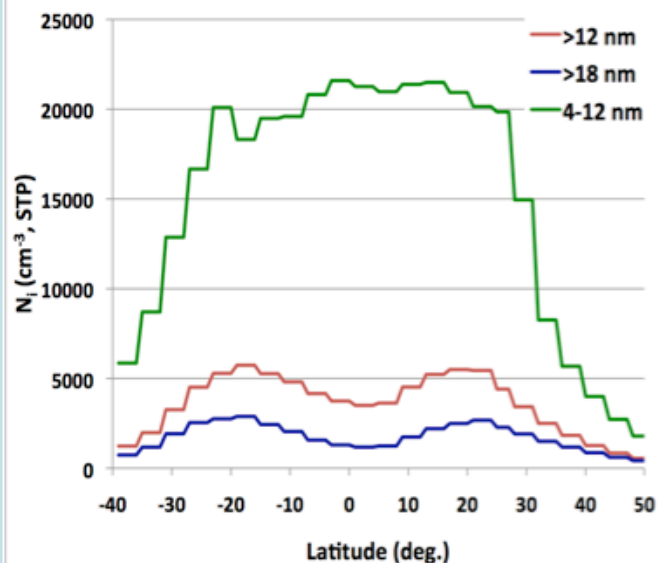
- Yu BHN similar to IMN

- Simulations have wider profiles than obs

Yu BHN

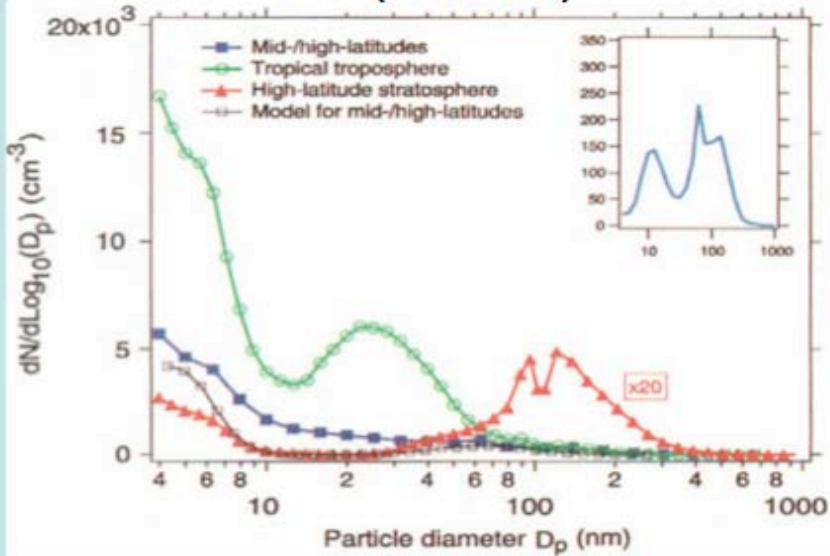


Yu IMN

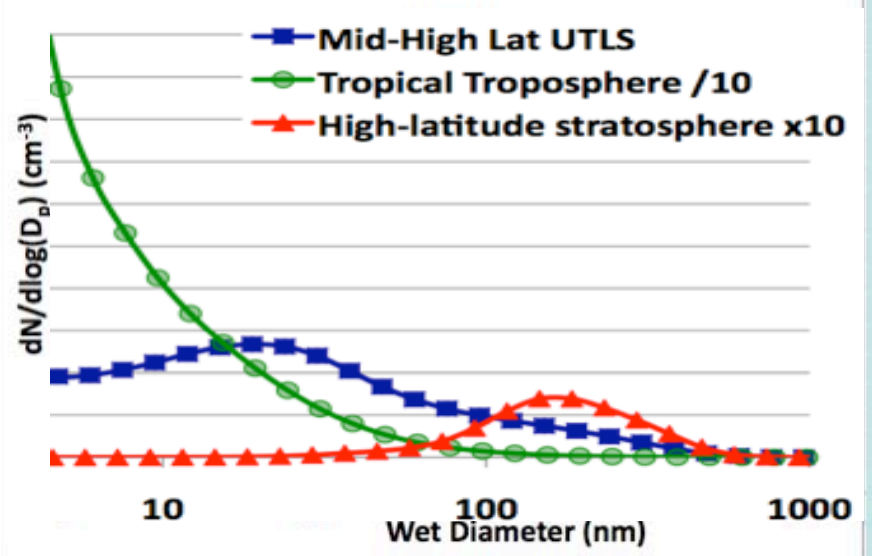


Size Distribution

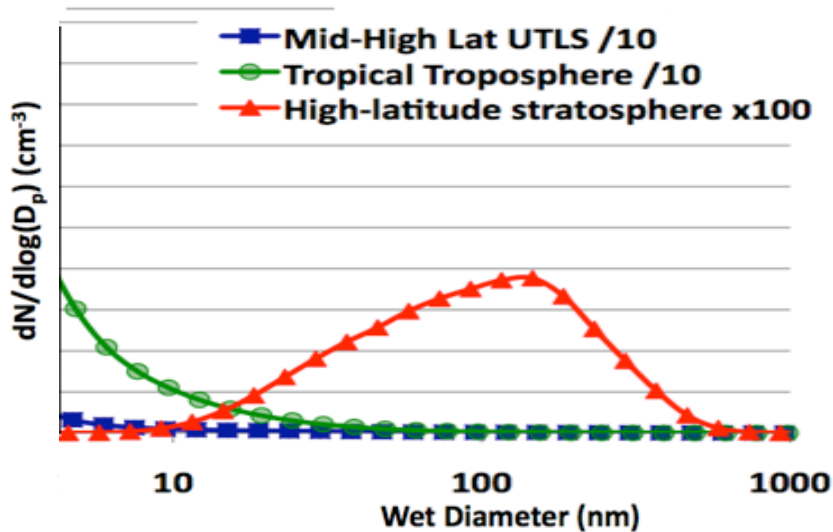
Obs. (Lee 2003)



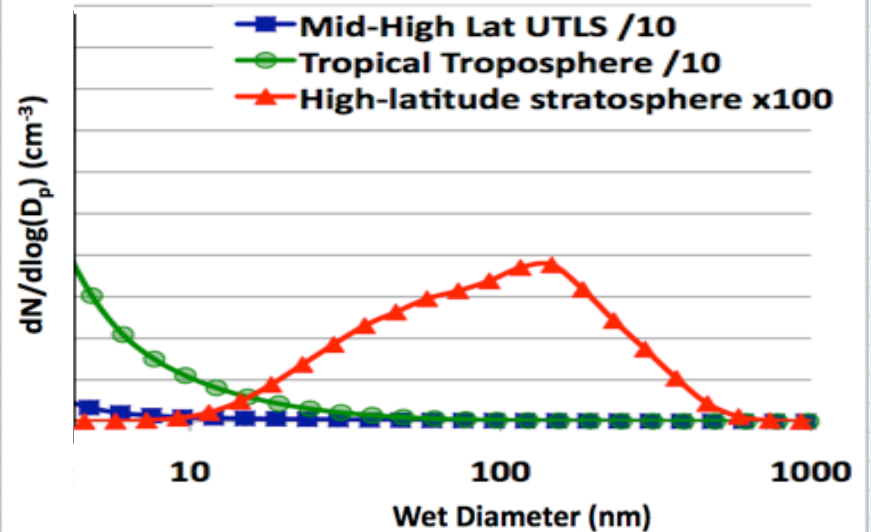
Zhao BHN



Yu BHN

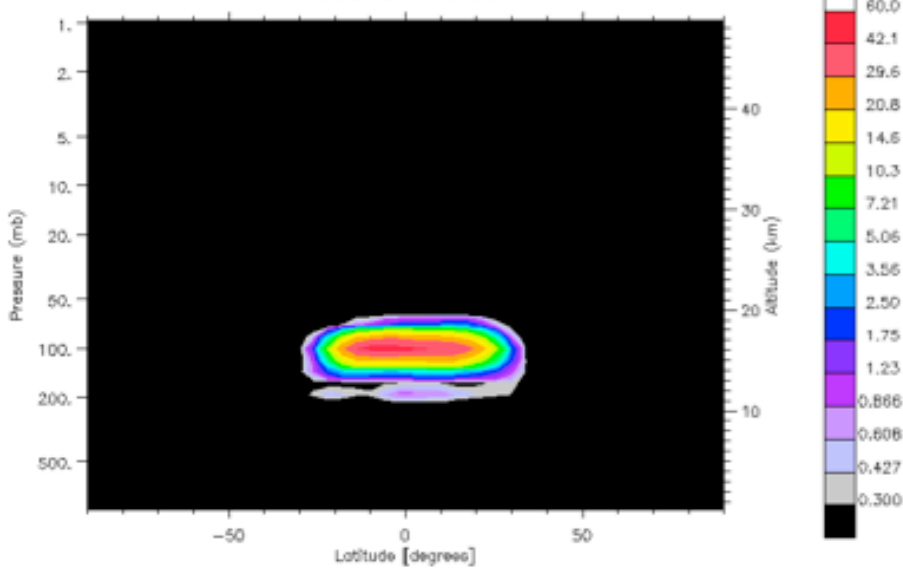


Yu IMN

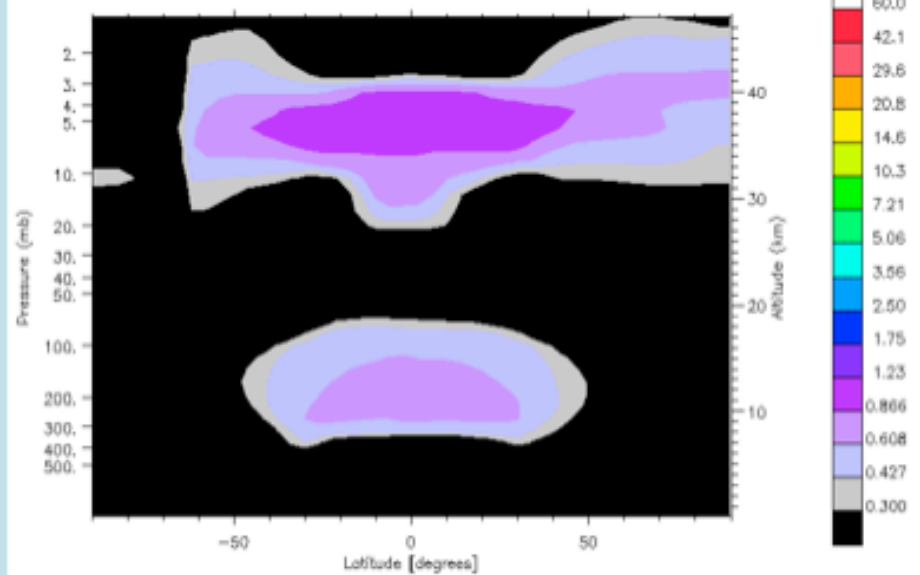


Sulfate Nucleation Rates

Zhao BHN

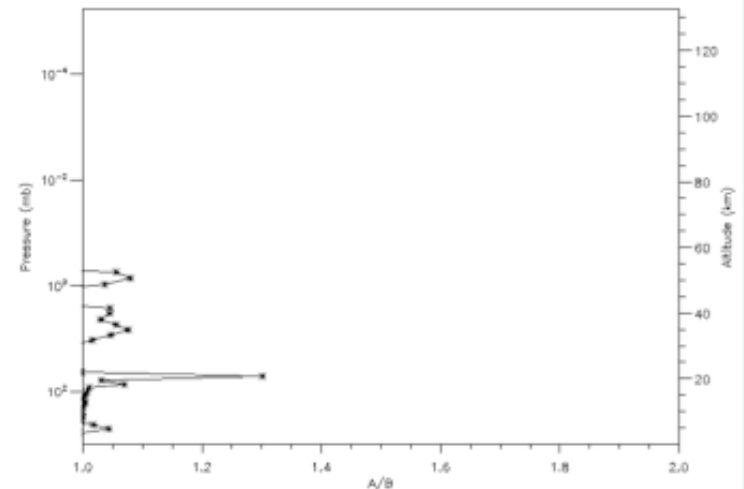


Yu BHN



- Zhao BHN rates 100 times higher than Yu BHN in tropical UTLS
- Yu BHN extend to mid-troposphere and upper stratosphere
- Yu IMN increases nucleation by up to 30% over Yu BHN

Yu IMN fractional increase



WACCM* vs Yu Lookup Table Ranges

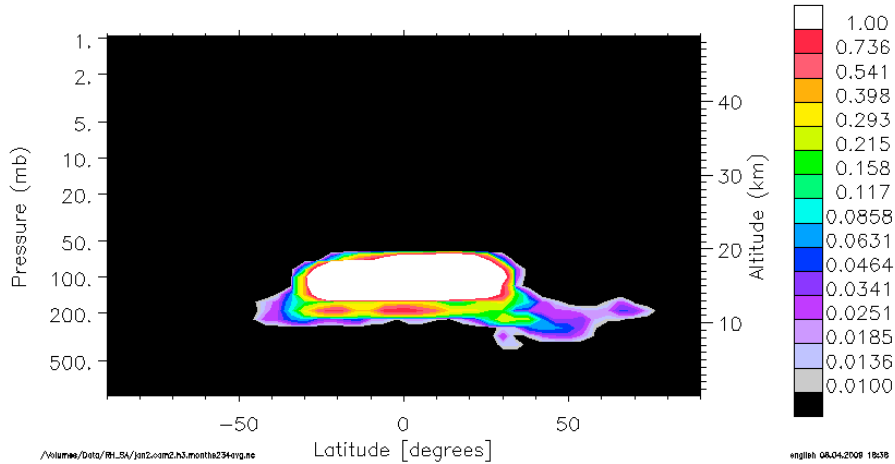
	Min		Max	
	Yu	WACCM	Yu	WACCM
T (K)	180	180	300	316
RH (%)	0.1	$1e^{-4}$	99.5	111
SA ($\mu\text{m}^2/\text{cm}^3$)	1	0	100	<100
H ₂ SO ₄ ($\#/\text{cm}^3$)	$1e^5$	0.5	$1e^8$	$3e^8$

* WACCM troposphere + stratosphere

RH & SA out of bounds drives nuc rate

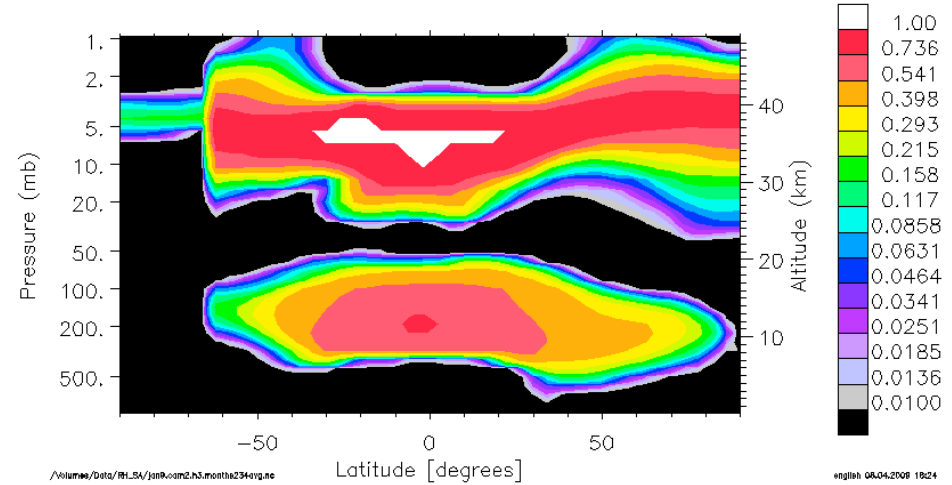
Zhao BHN

RHOMNUC [$/\text{cm}^3/\text{s}$], 15Mar1995 00:00, lon average



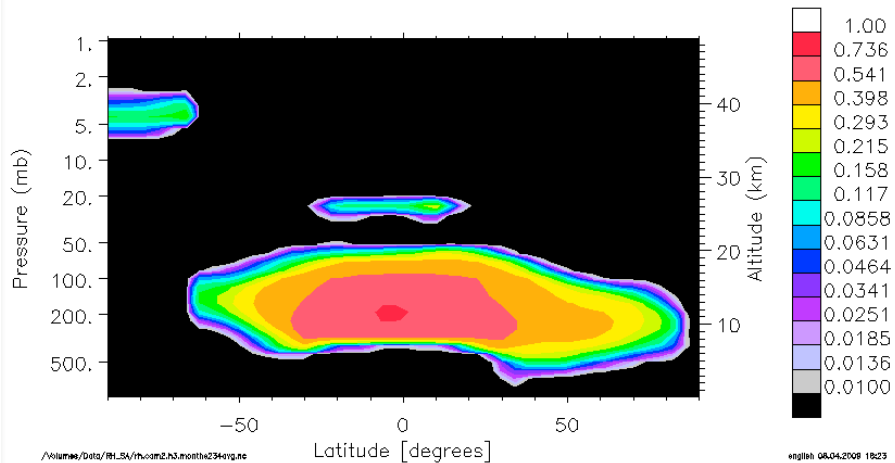
Yu BHN

RHOMNUC [$/\text{cm}^3/\text{s}$], 15Mar1995 00:00, lon average



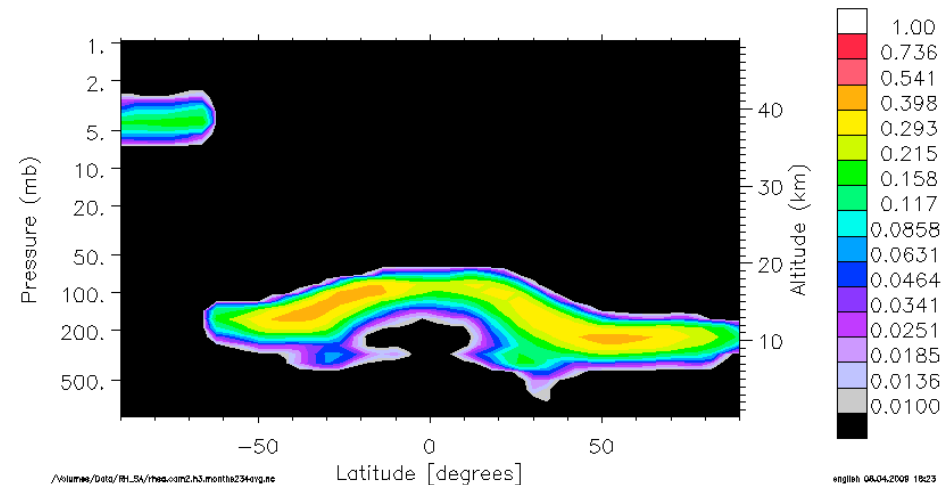
Yu BHN: RH cutoff

RHOMNUC [$/\text{cm}^3/\text{s}$], 15Mar1995 00:00, lon average



Yu BHN: RH & SA cutoff

RHOMNUC [$/\text{cm}^3/\text{s}$], 15Mar1995 00:00, lon average



Next Steps

- **Run 2-year simulation setting nucleation to zero if $RH < 0.1\%$**
- **Extend the Lookup tables for more robust coupling with WACCM**
- **Improve sulfur dioxide emissions schemes**
- **Add micrometeoritic dust to nucleation schemes**

Acknowledgments

- **Brian Toon**
- **Mike Mills**
- **Fangqun Yu**
- **Chuck Bardeen**