# Trends in the Background Stratospheric Aerosol Layer

**Acknowledgement: Dr. Brian Toon, Dr. Michael Mills and Jason English for basis of current working model.**

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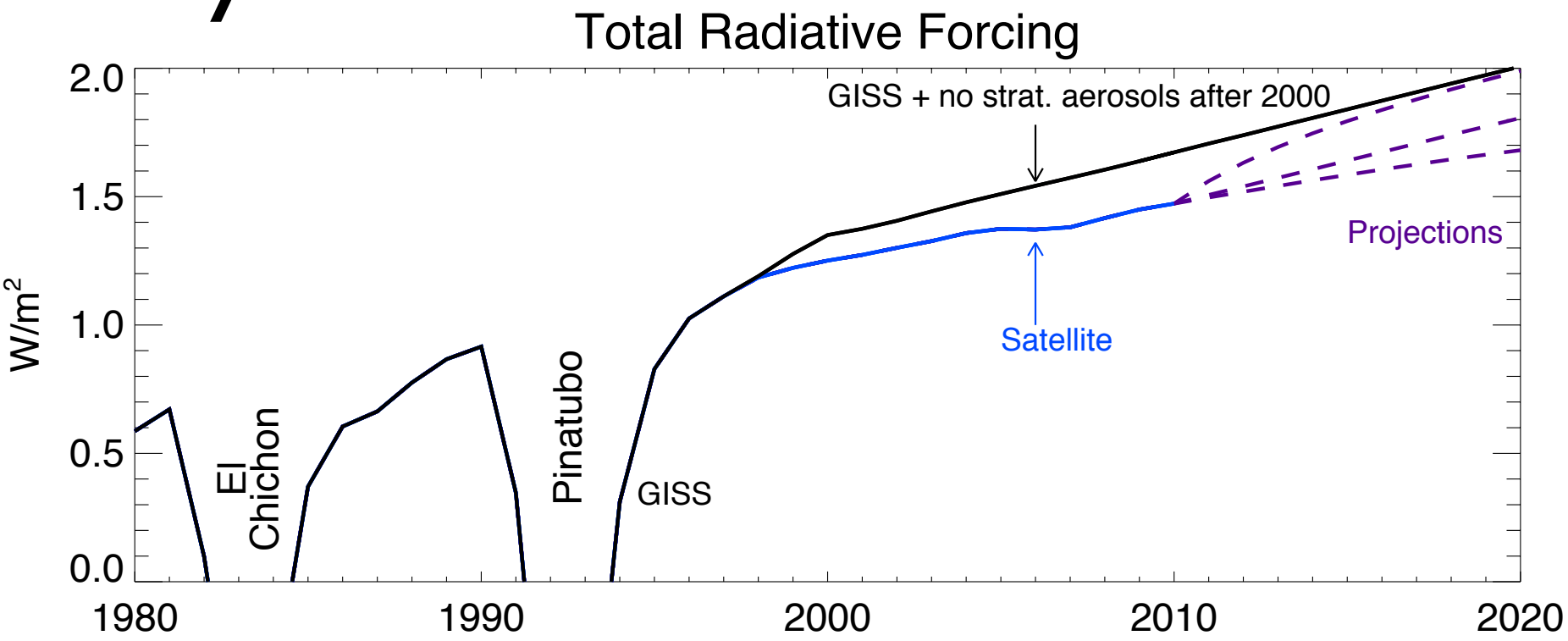
Susan Solomon, John Barnes, Ellsworth Dutton



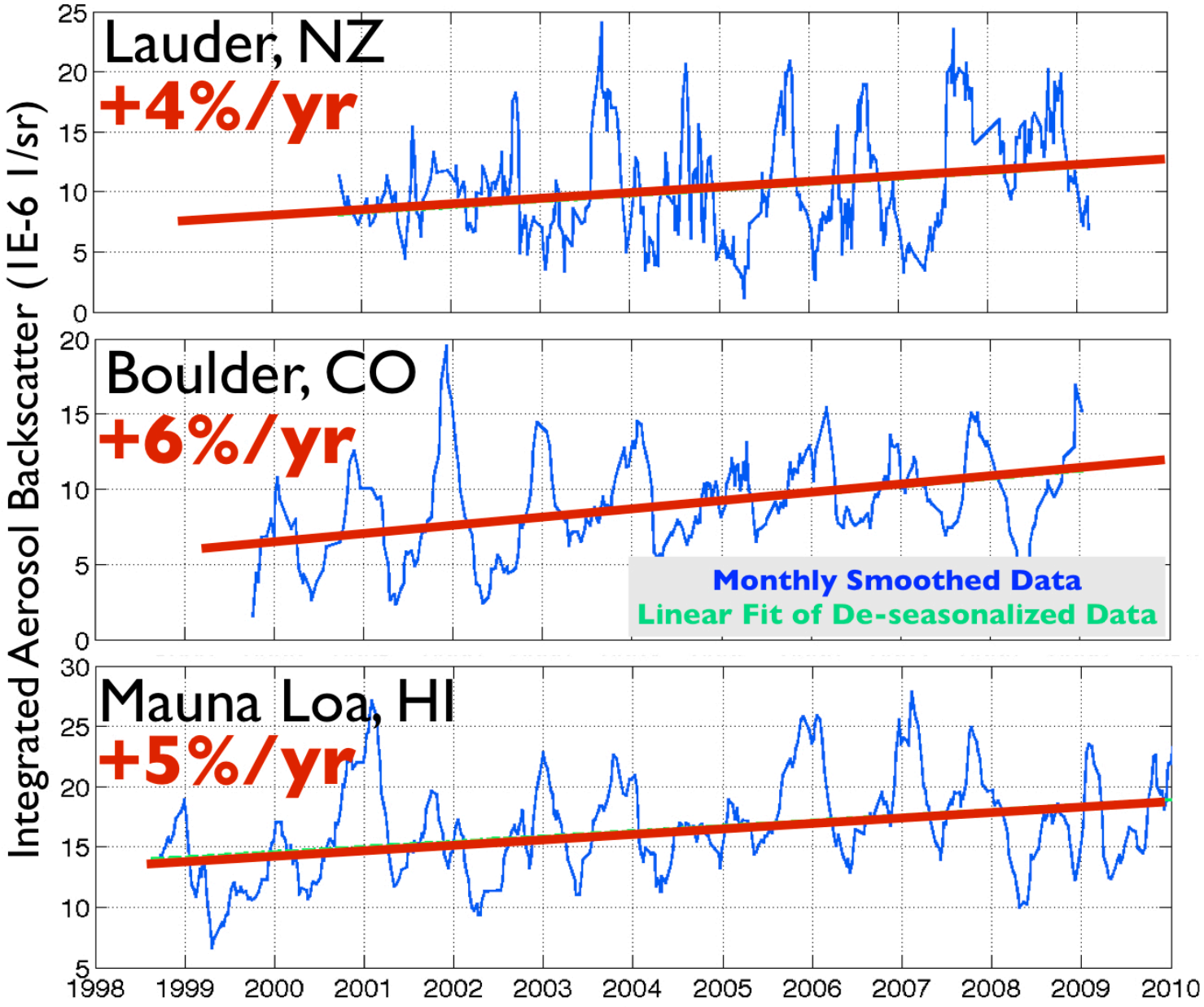

# Why?




Adapted From: Solomon, S., J. S. Daniel, R. R. Neely, J. P. Vernier, E. G. Dutton, and L. W. Thomason (2011), The Persistently Variable "Background" Stratospheric Aerosol Layer and Global Climate Change, Science, 333(6044), 866–870, doi:10.1126/science.1206027.

See Daniel et al. tomorrow at 17:45 for the "The persistently variable "Background" stratospheric aerosol layer and global climate change.

# 5km Integrated Aerosol Backscatter Layer Centered at 27.5 km



# Lidars and Satellites **Agree** on Trend

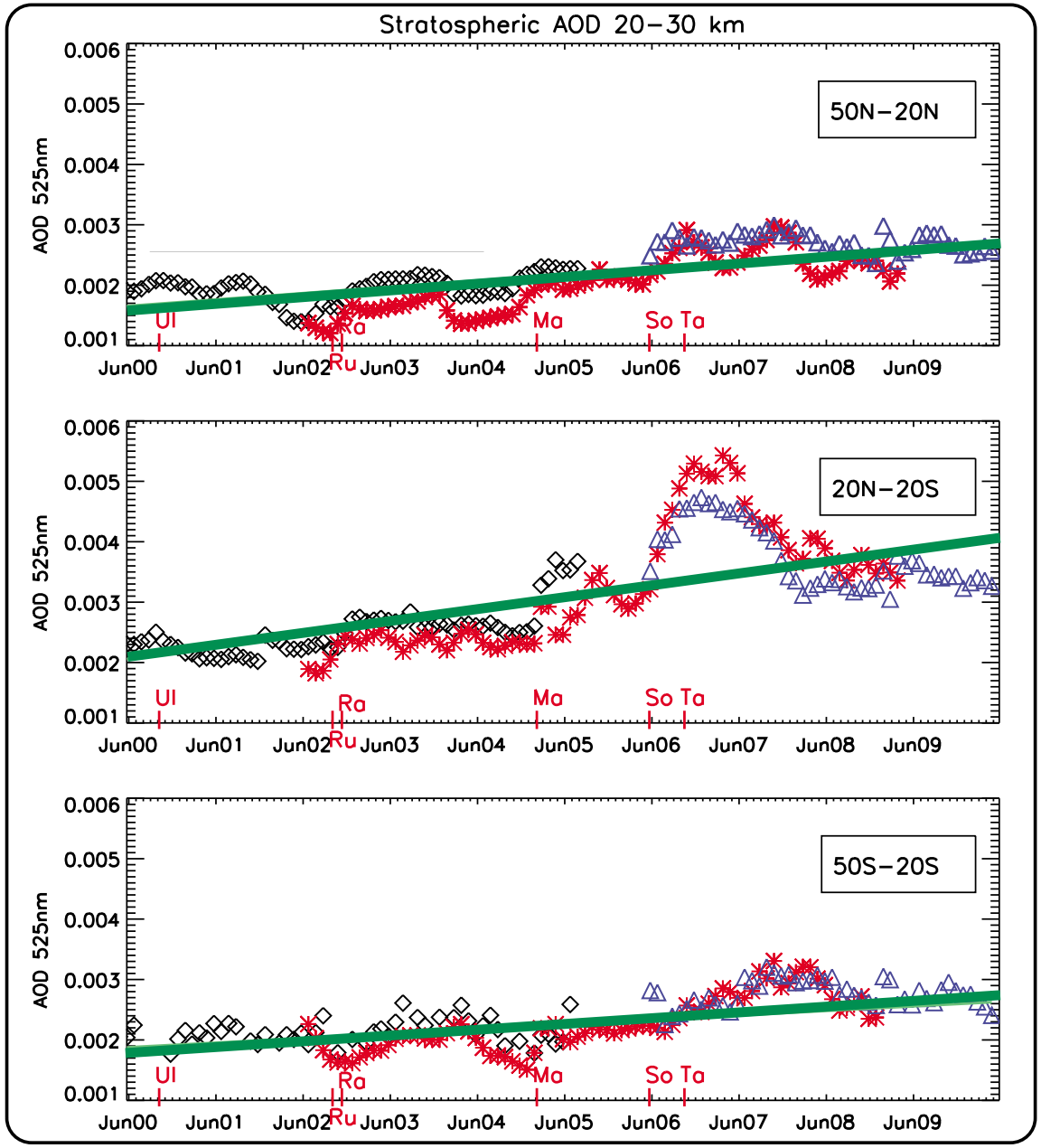
◇ SAGE II

✳ GOMOS

△ CALIPSO

LINEAR FIT

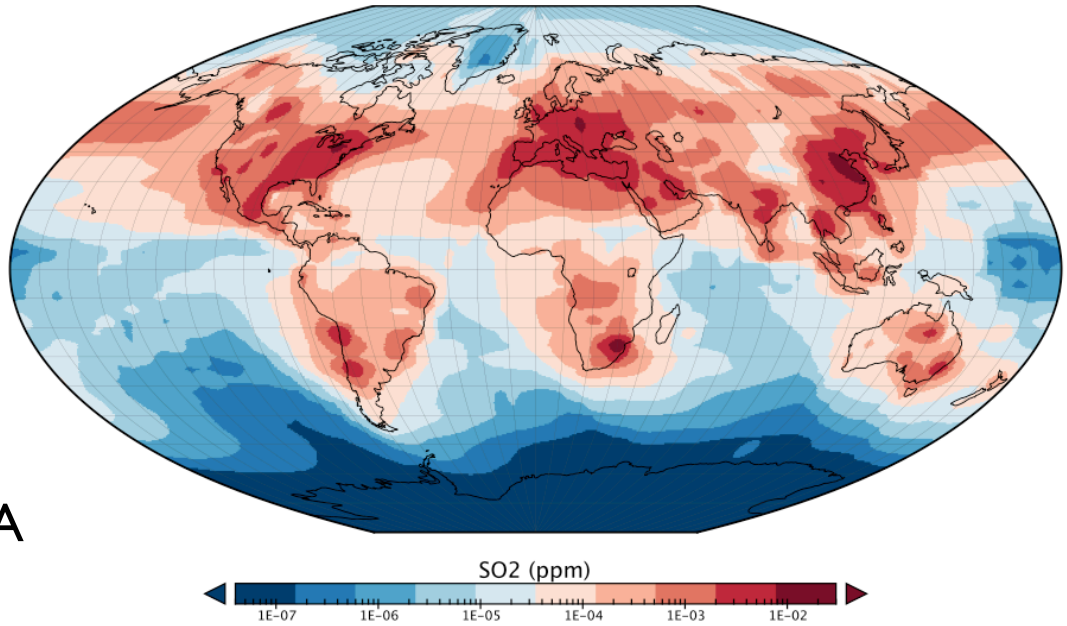
**+4-7%/yr**




Adapted from: Vernier, J. P. et al. (2011), Major influence of tropical volcanic eruptions on the stratospheric aerosol layer during the last decade, Geophys. Res. Lett, 38(12)

# Model Description

January Model Surface $SO_2$ Concentrations

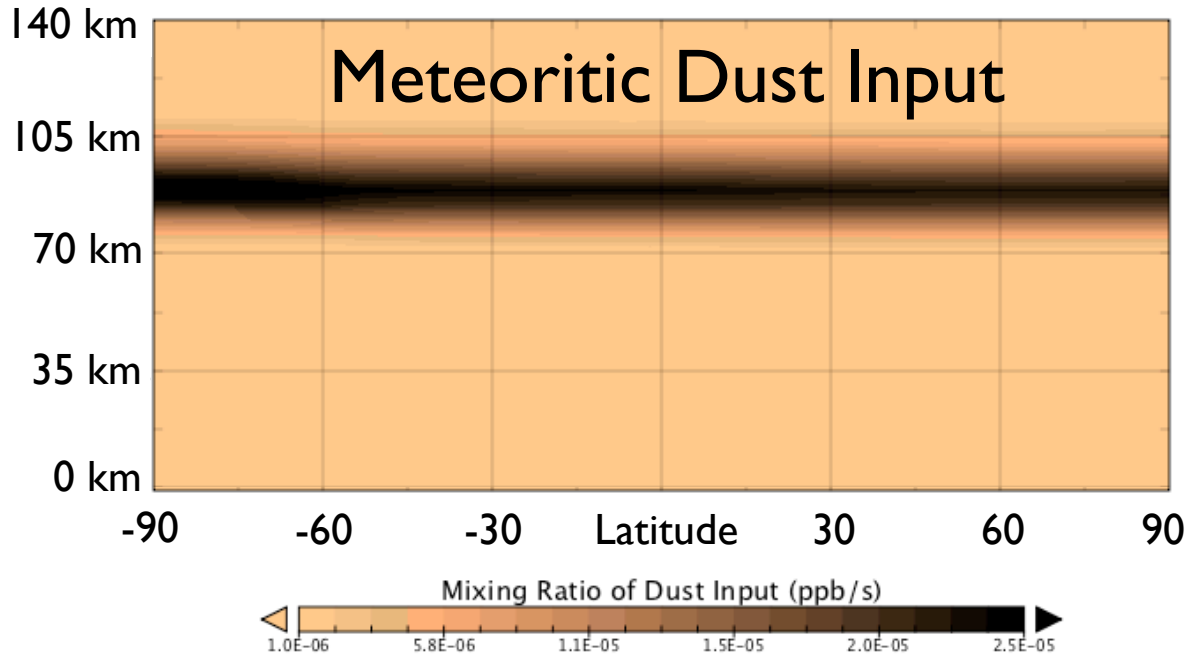



- NCAR's WACCM with CARMA
- 3D chemical transport Model for OZone And Related chemical Tracers (MOZART)(Horowitz et al. 2003)
- Sulfur chemistry includes seven sulfur species: $SO_2$, $SO_3$, SO, $H_2SO_4$, $CS_2$ and OCS (English et al., 2011(ACPD))
  - $SO_2$ Emission data representative of background aerosol period (Smith et al. (2010) and English et al., 2011(ACPD)).

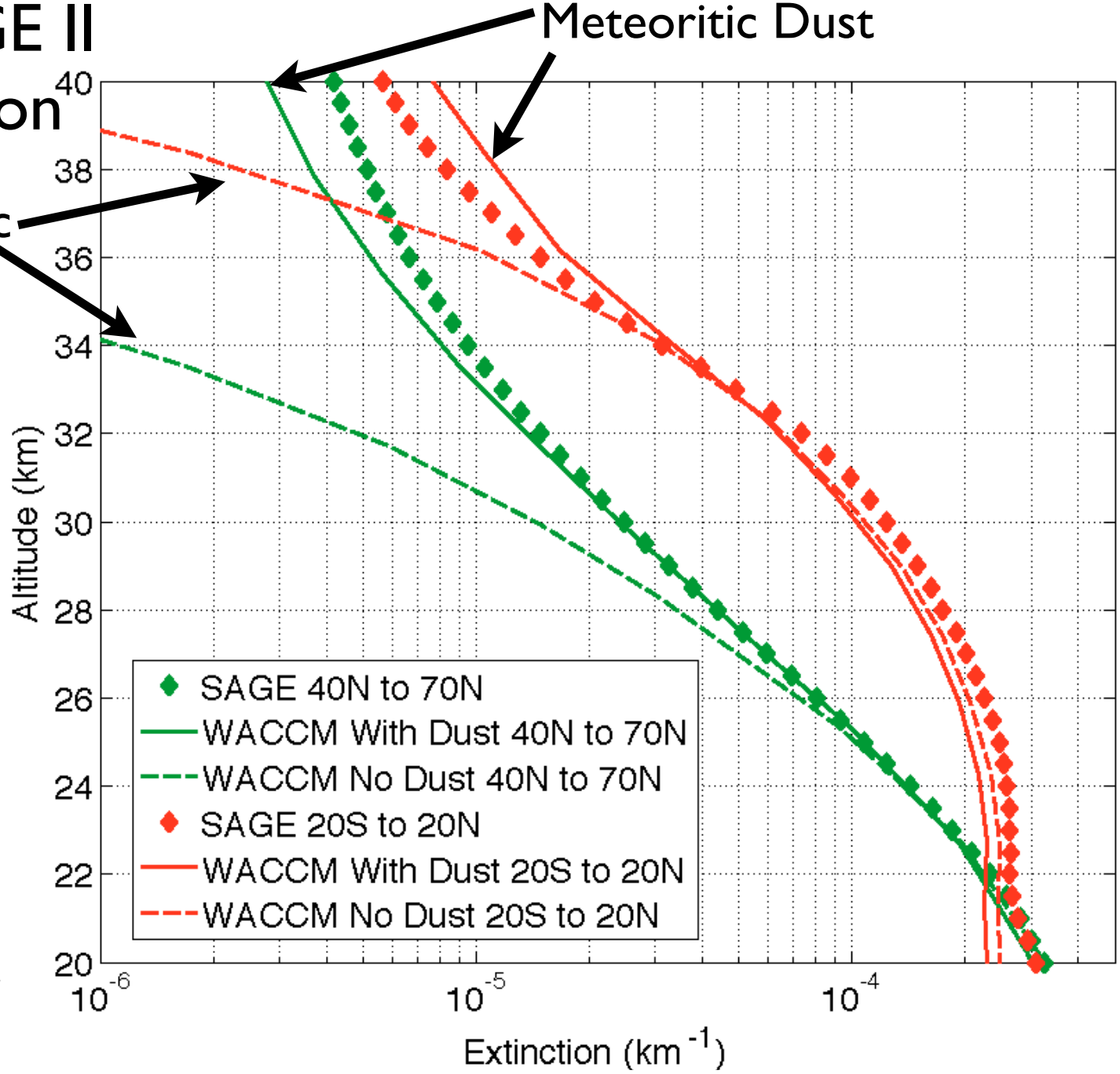
# CARMA Setup

**C**ommunity
**A**erosol and
**R**adiation
**M**odel for
**A**tmospheres

- Aerosol Size Distributions created by 36 bins (dry radii from 0.2 nm to 1100 nm) each for:
  - Pure sulfates (English et al., 2011)
  - Meteoritic dust (Murphy et al. 2007, Bardeen et al. 2008)
  - Mixed sulfates (sulfate aerosols with dust cores)

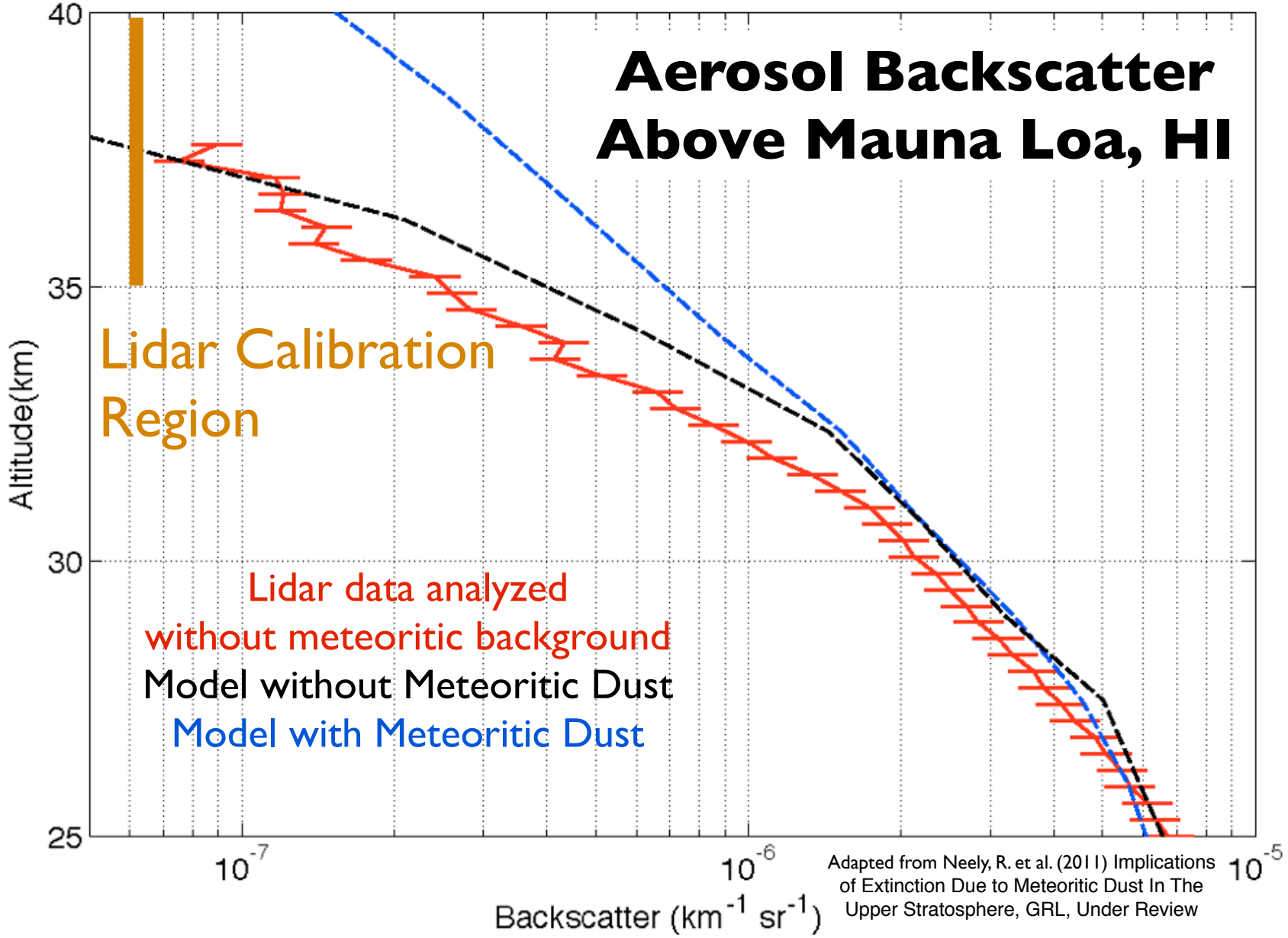


# Model-SAGE II Comparison




Adapted from Neely, R. et al. (2011) Implications of Extinction Due to Meteoritic Dust In The Upper Stratosphere, GRL, Under Review

# Meteoritic Dust Needs to Be Considered in Models and Measurements

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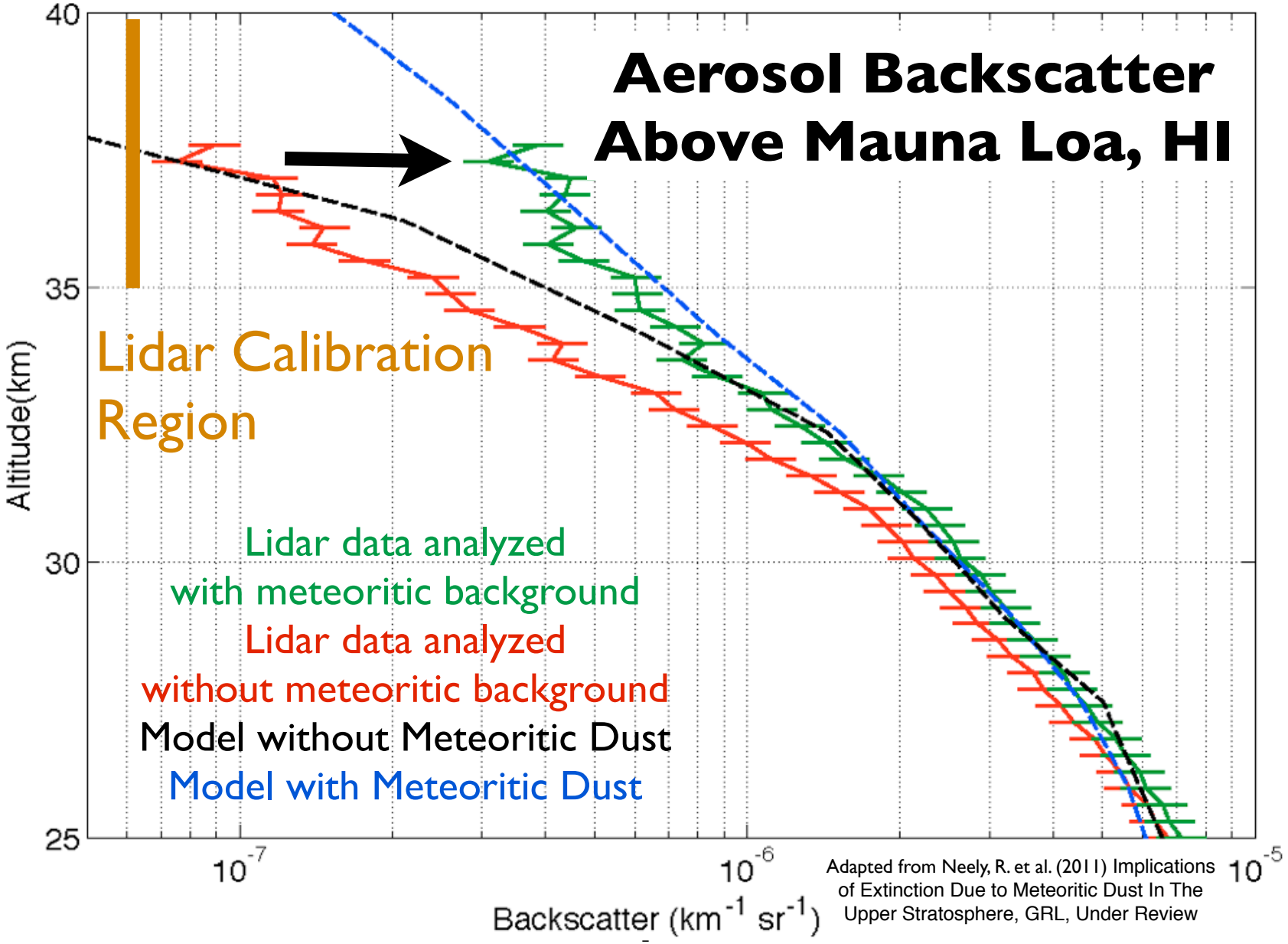


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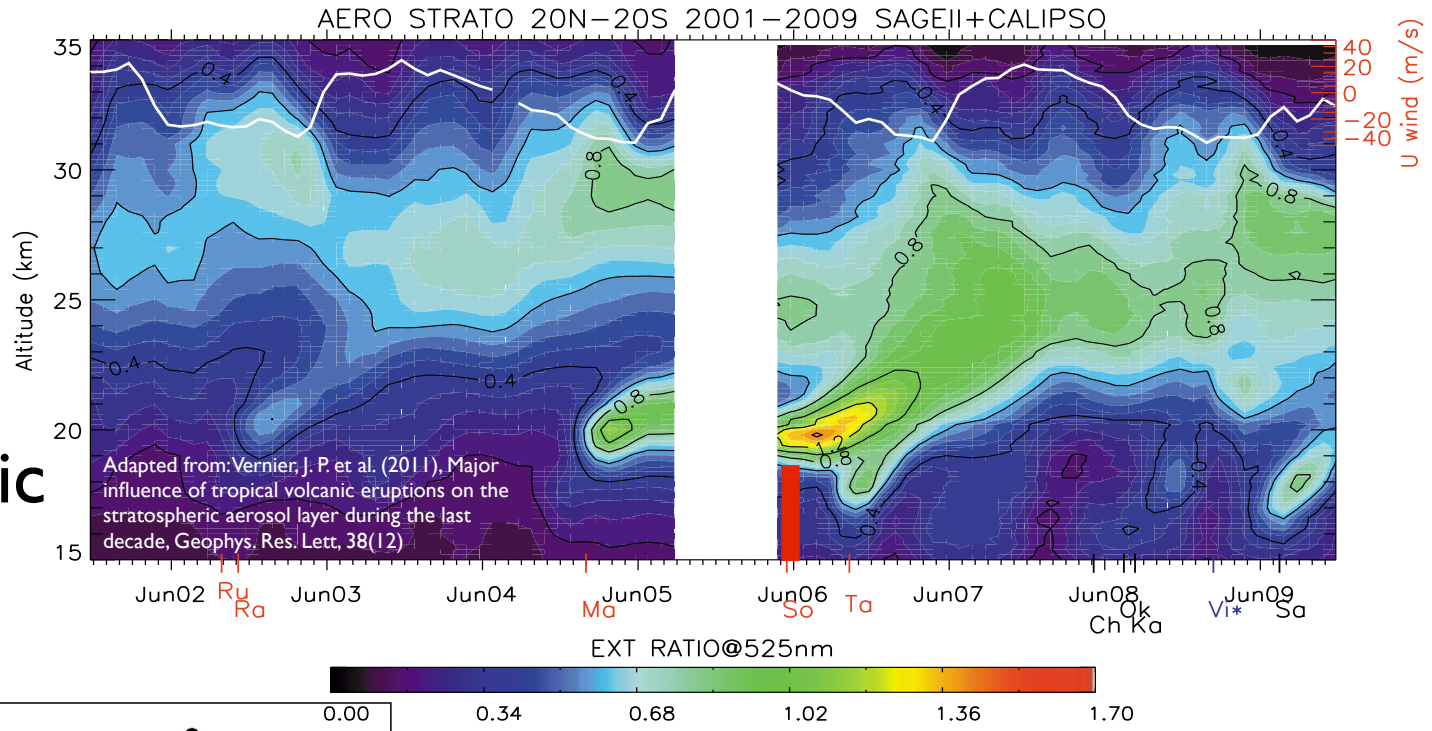
# Trends?

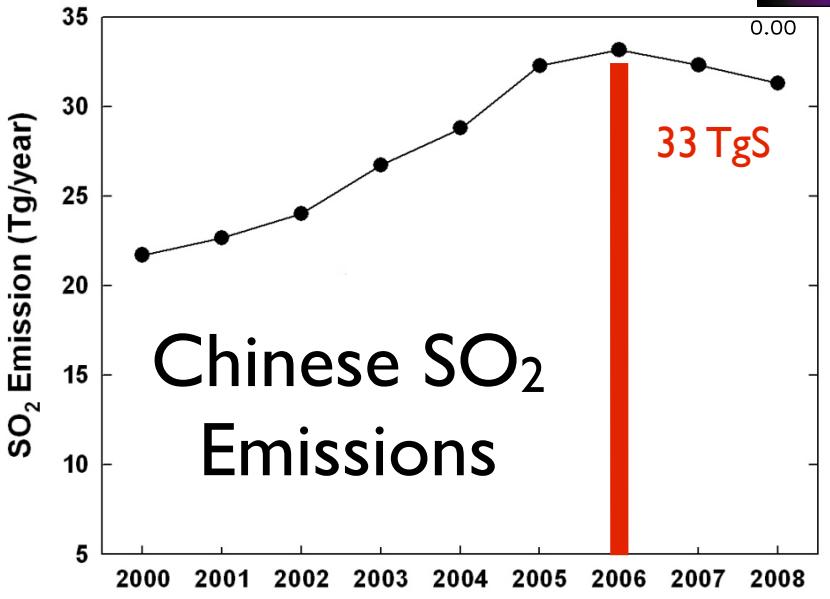
Possible theories:

Anthropogenic emissions
(Hofmann et al. 2009,
Randel et al. 2010)

Small episodic injections
(Vernier et al. 2009 and 2011)

# Volcanic Vs. Anthropogenic Emissions




Lu, Z., D. G. Streets, Q. Zhang, S. Wang, G. R. Carmichael, Y. F. Cheng, C. Wei, M. Chin, T. Diehl, and Q. Tan (2010), Sulfur dioxide emissions in China and sulfur trends in East Asia since 2000, *Atmos. Chem. Phys*, *10*(13)

## Estimated Emission to Stratosphere

(0.6% of Global Emissions must make it to stratosphere to maintain sulfur burden (Hofmann et al. 2009))

| Year | China | Volcano |
|---|---|---|
| 2006 | 0.23 TgS | Soufrière Hills 0.17 TgS |

# Why Are Volcanoes More Efficient at Making Aerosol?

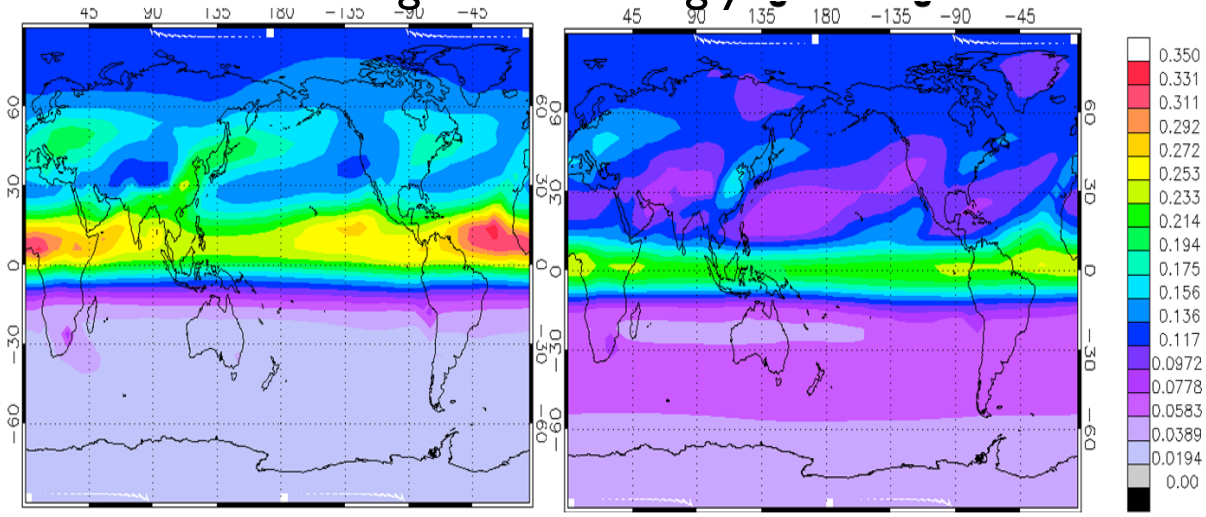
1st Order: Direct Injection. (No rainout)

2nd Order: Microphysics

Aerosol Optical

Pinatubo 10Tg

10Tg/yr Continuos

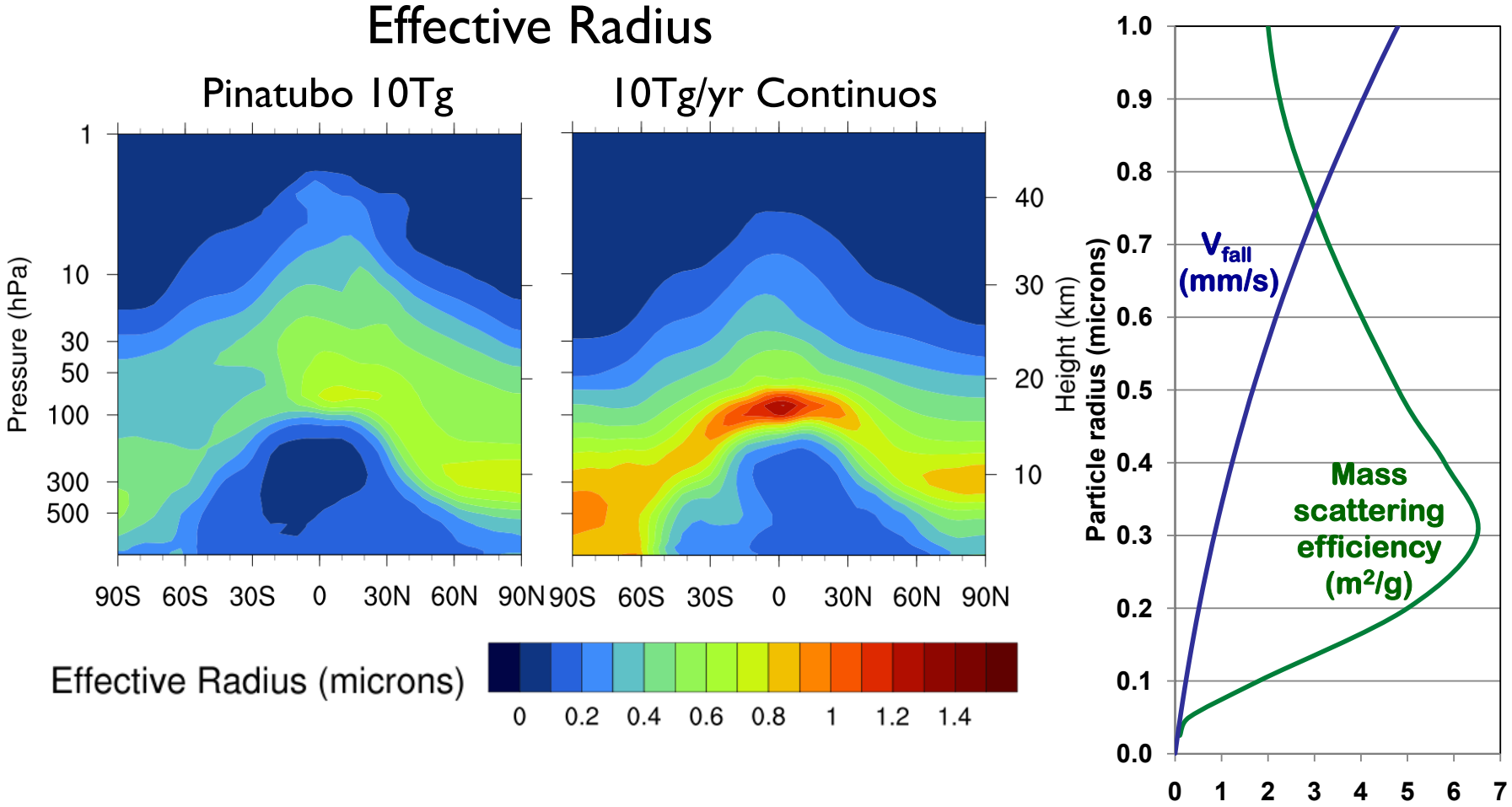



Pinatubo =10 TgS, 48-hr **burst** at 216°N – 4°S, 92.5°E – 117.5°E, between 15.1-28.5 km with a 20-km peak

10 TgS/yr = 10 Tg S/yr released **continuously** at 4°N – 4°S, all longitudes, between 18.8 –19.9 km

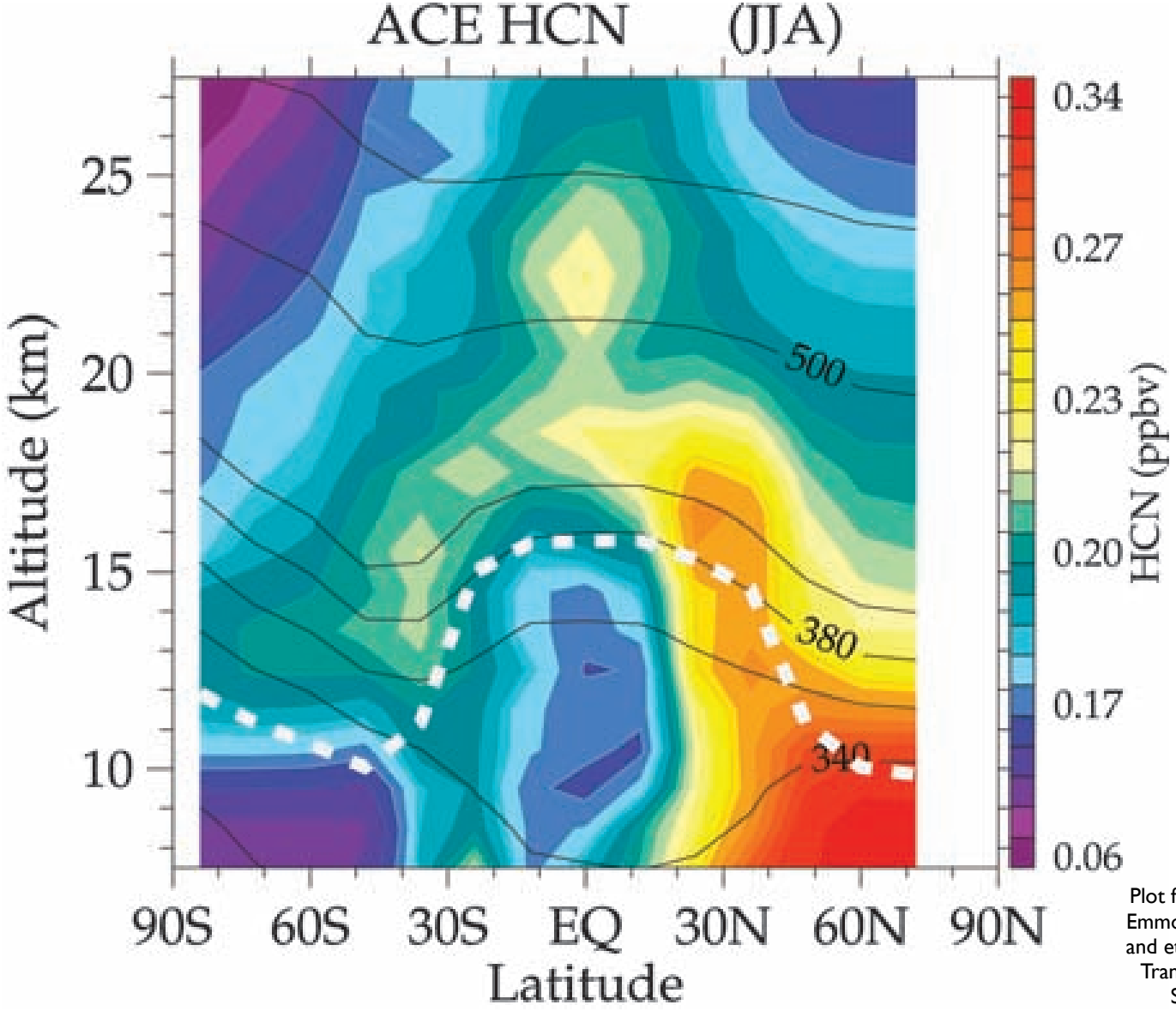
Plots adapted from English, J. M., O. B. Toon, and M. J. Mills (2011), Microphysical simulations of stratospheric sulfur geoengineering, *J. Geophys. Res.,* under review.

# Why Are Volcanoes More Efficient at Making Aerosol?




Plots adapted from English, J. M., O. B. Toon, and M. J. Mills (2011), Microphysical simulations of stratospheric sulfur geoengineering, *J. Geophys. Res.,* under review.

# Could the Asian Monsoon be Acting as a Seasonal "Volcano" like Source?

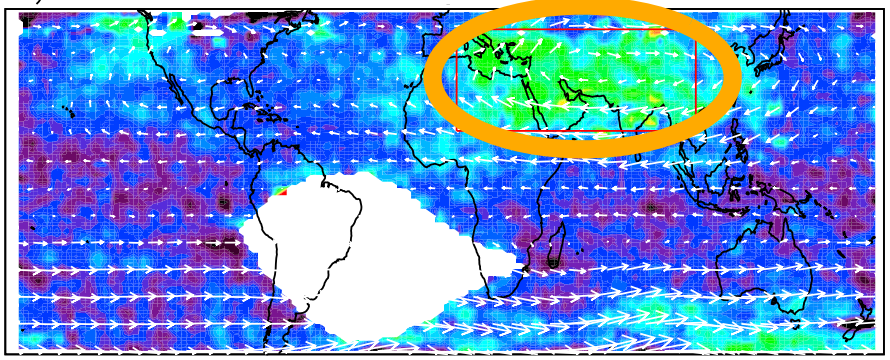



Plot from Randel, W., M. Park, L. Emmons, D. Kinnison, P. Bernath, and et al (2010), Asian Monsoon Transport of Pollution to the Stratosphere, Science.

# Mean Scattering Ratio (SR) from CALIPSO at 532 nm between **15–17 km**

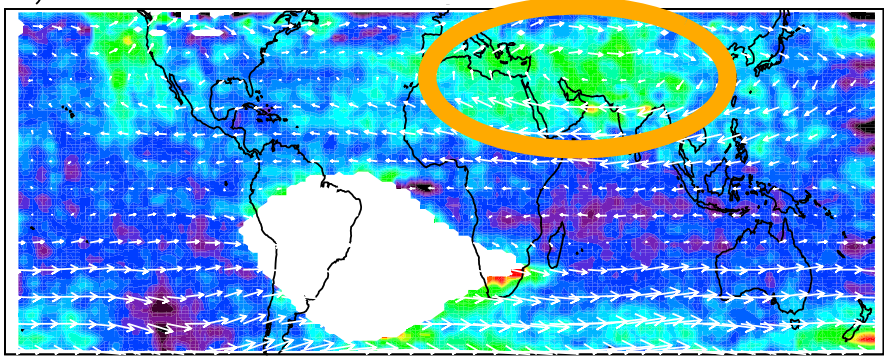
## Jun-Aug 2006

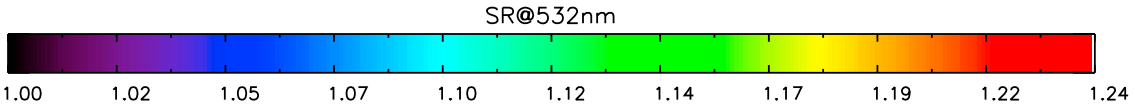
a)



## Jun-Aug 2007

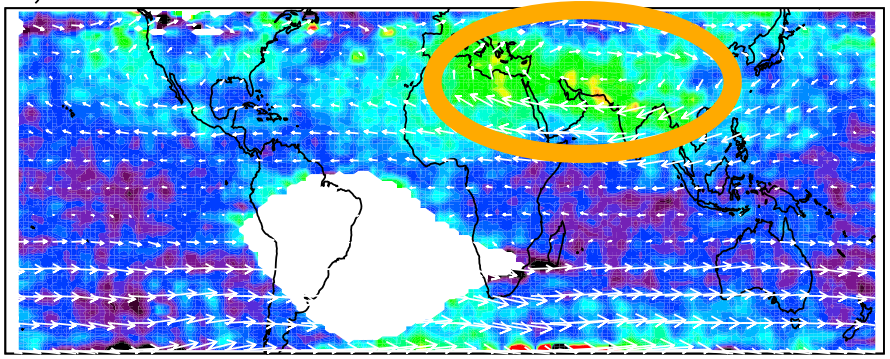
b)





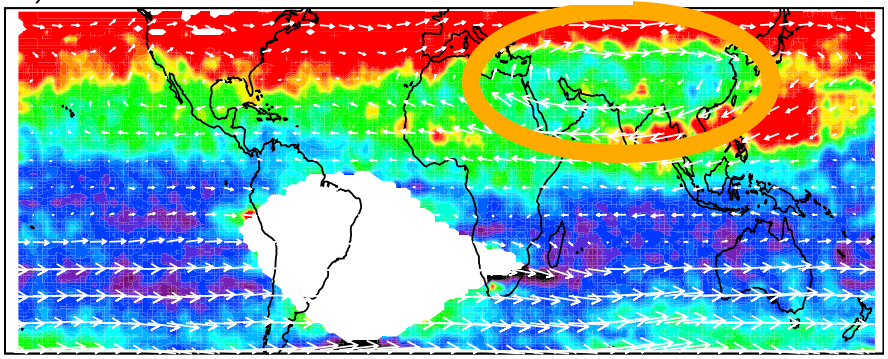

## Jun-Aug 2008

c)

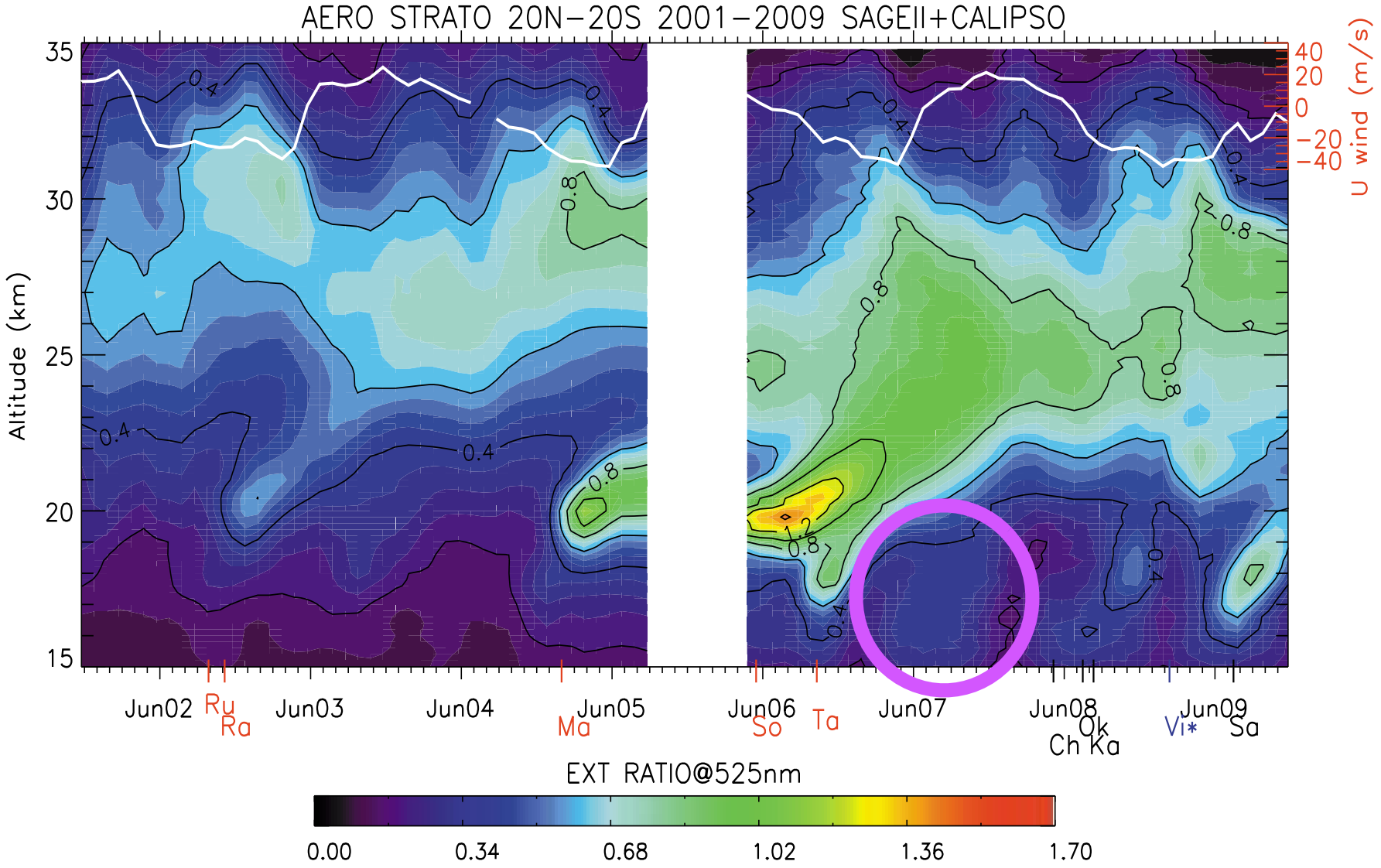


## Jun-Aug 2009

d)



Adapted from: Vernier, J. P., L. W. Thomason, and J. Kar (2011), CALIPSO detection of an Asian tropopause aerosol layer, Geophys. Res. Lett, 38(7), doi:10.1029/2010GL046614.




# 2007 Had an Enhanced Asian Monsoon and No Large Eruption Disturbed the Stratosphere

Adapted from: Vernier, J. P. et al. (2011), Major influence of tropical volcanic eruptions on the stratospheric aerosol layer during the last decade, Geophys. Res. Lett, 38(12)

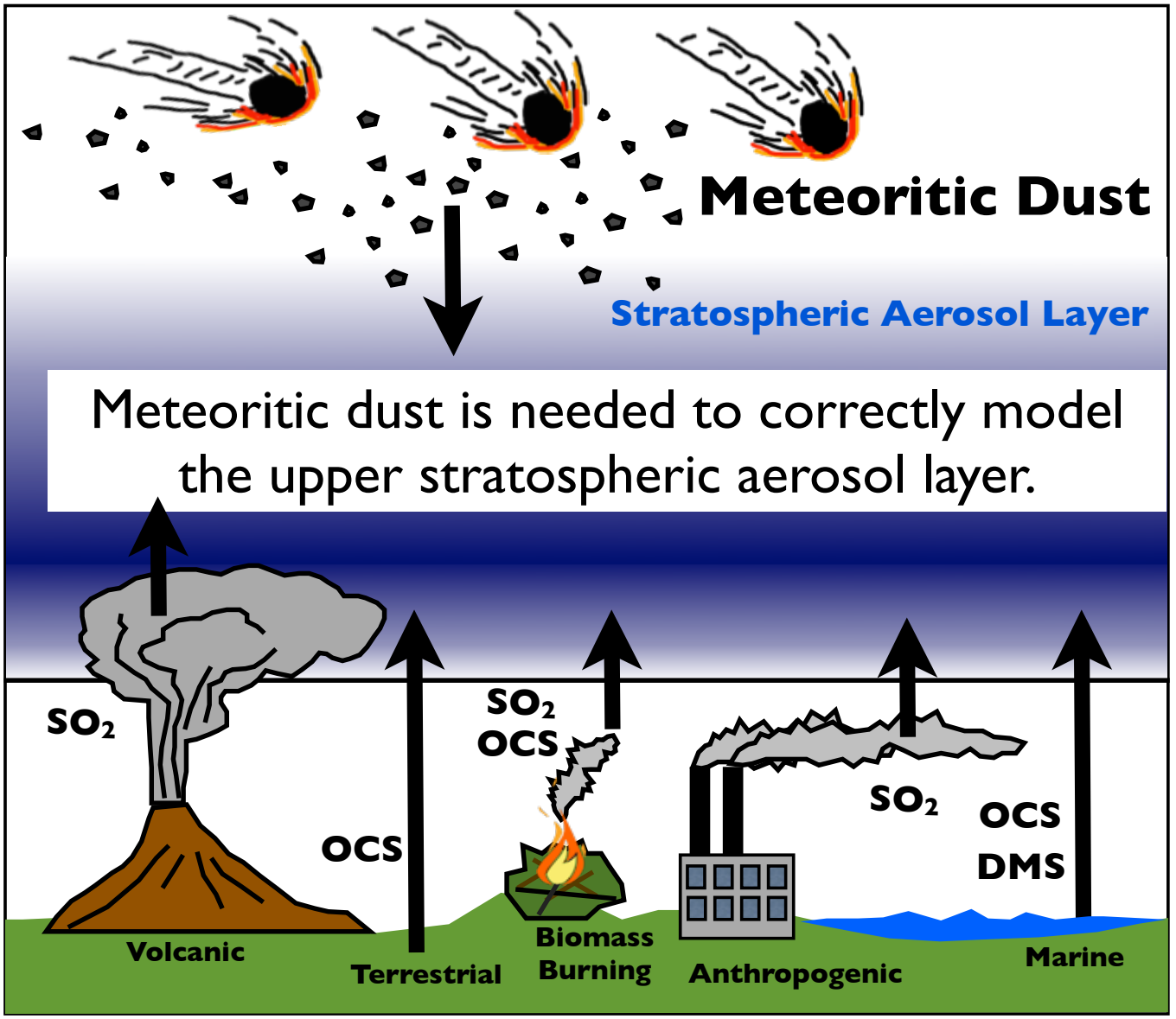
# Summary

Mesosphere

Stratosphere

Troposphere

Surface



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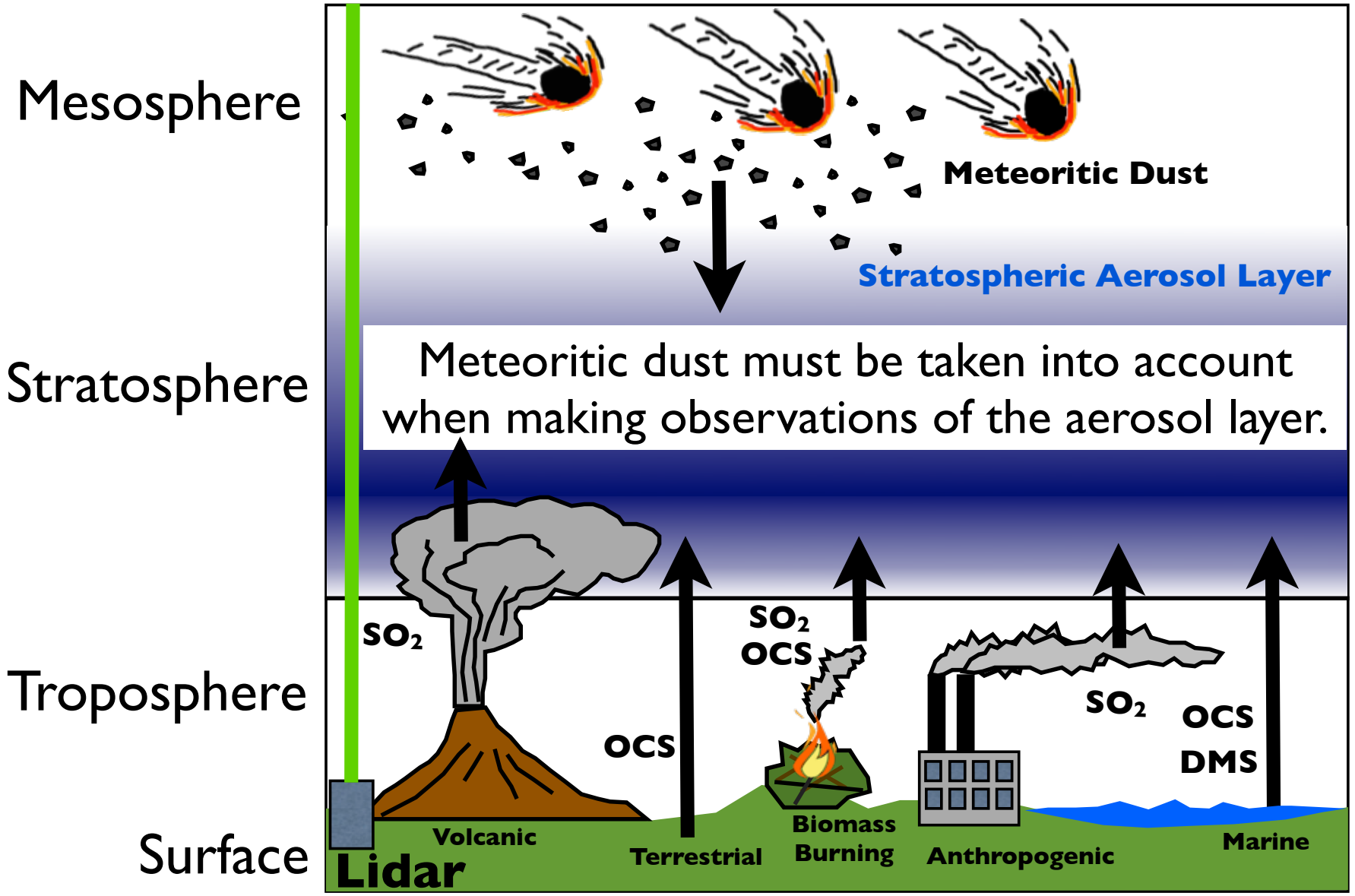
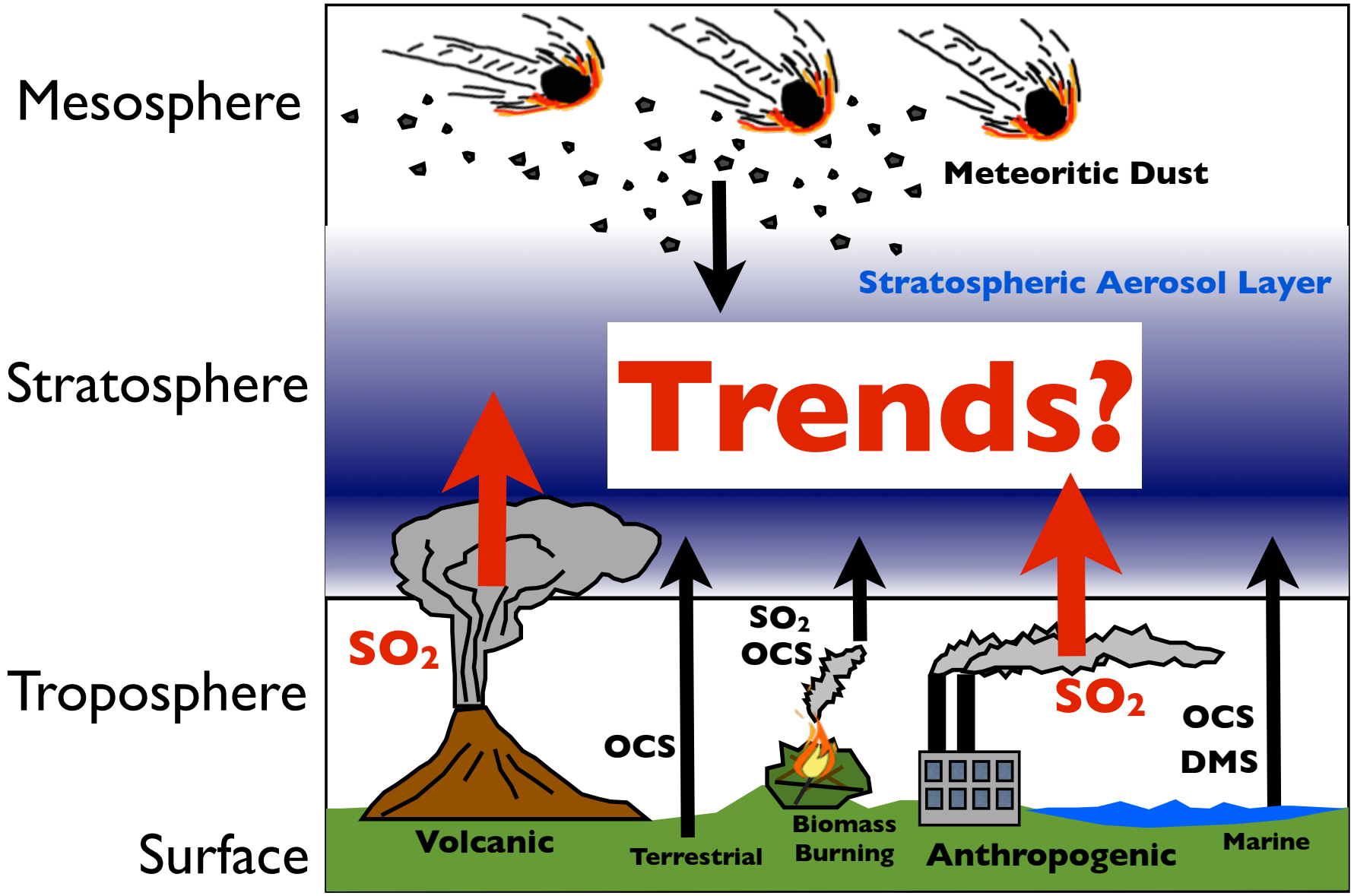

Mesosphere
Stratosphere
Troposphere
Surface
Meteoritic Dust
Stratospheric Aerosol Layer
Meteoritic dust must be taken into account when making observations of the aerosol layer.
SO2
OCS
SO2
OCS
SO2
OCS
DMS
Volcanic
Lidar
Terrestrial
Biomass Burning
Anthropogenic
Marine

# Summary


Mesosphere
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SO2
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