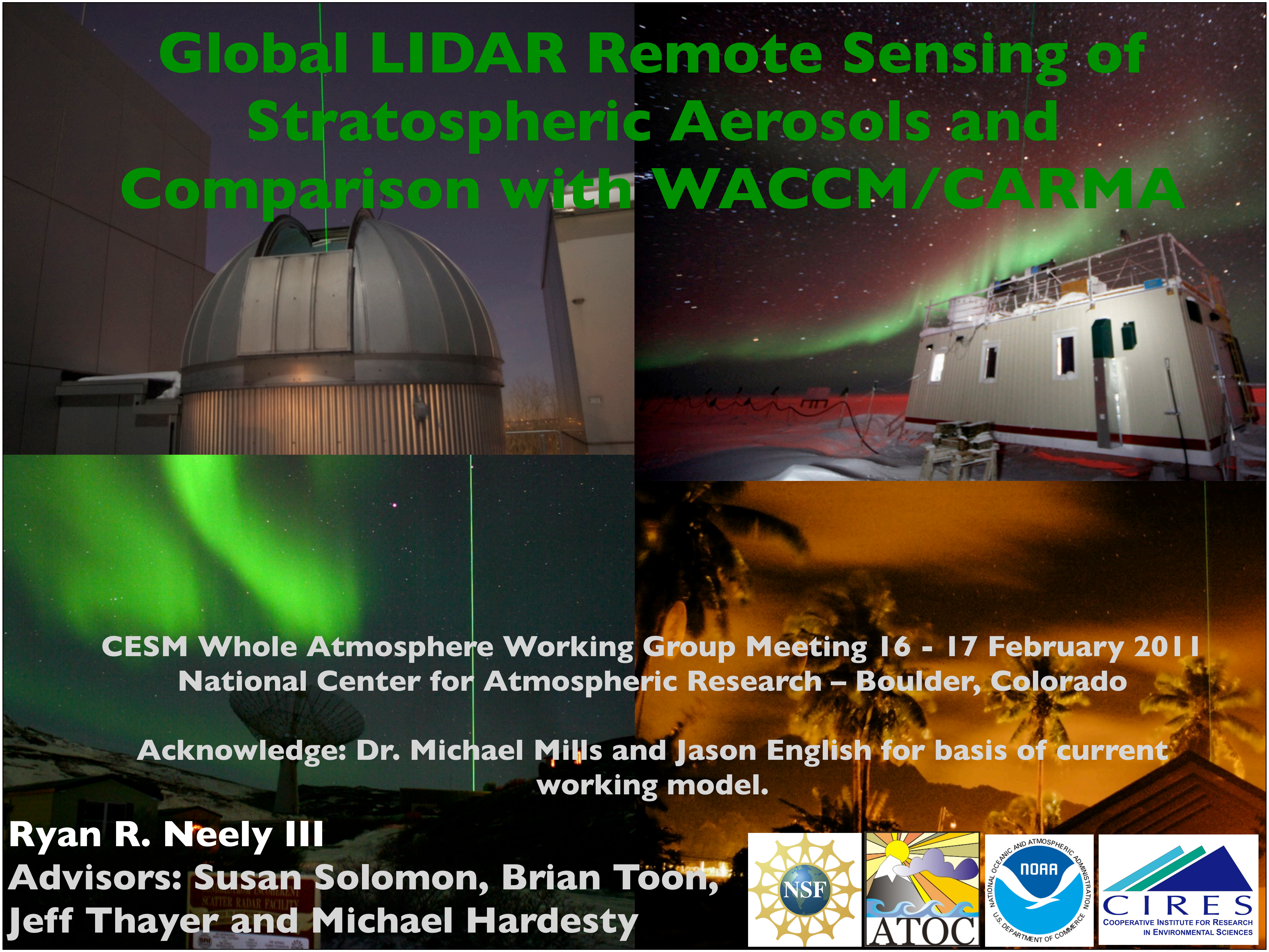

Global LIDAR Remote Sensing of Stratospheric Aerosols and Comparison with WACCM/CARMA

CESM Whole Atmosphere Working Group Meeting 16 - 17 February 2011
National Center for Atmospheric Research – Boulder, Colorado

Acknowledge: Dr. Michael Mills and Jason English for basis of current working model.

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Advisors: Susan Solomon, Brian Toon, Jeff Thayer and Michael Hardesty

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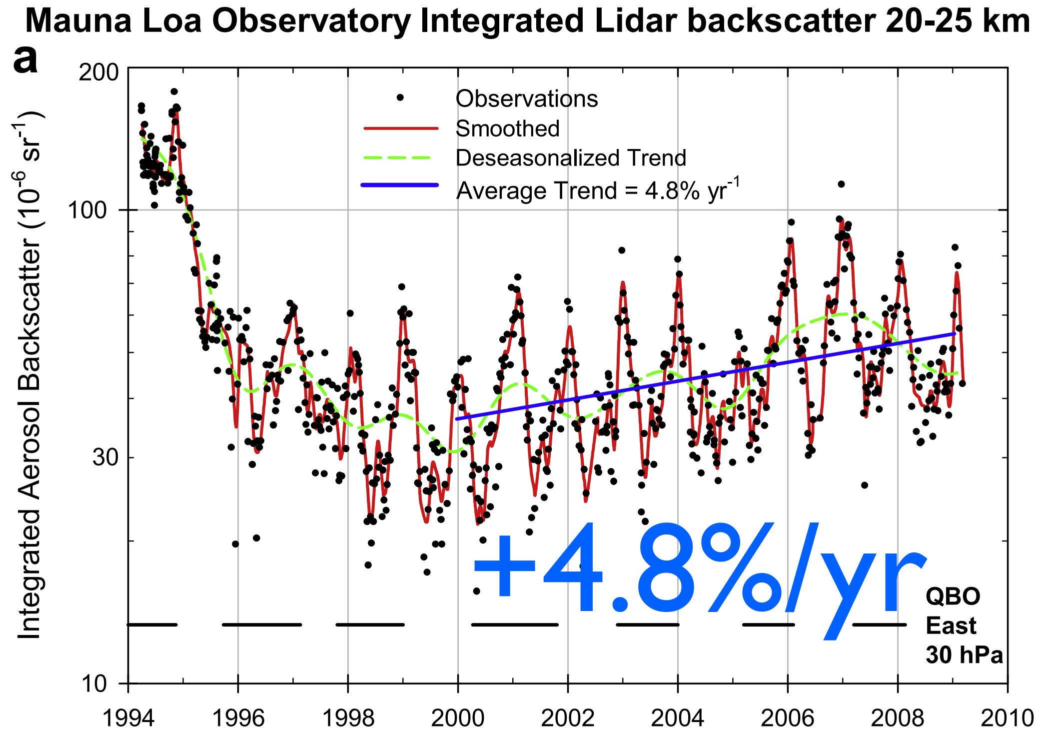
Introduction

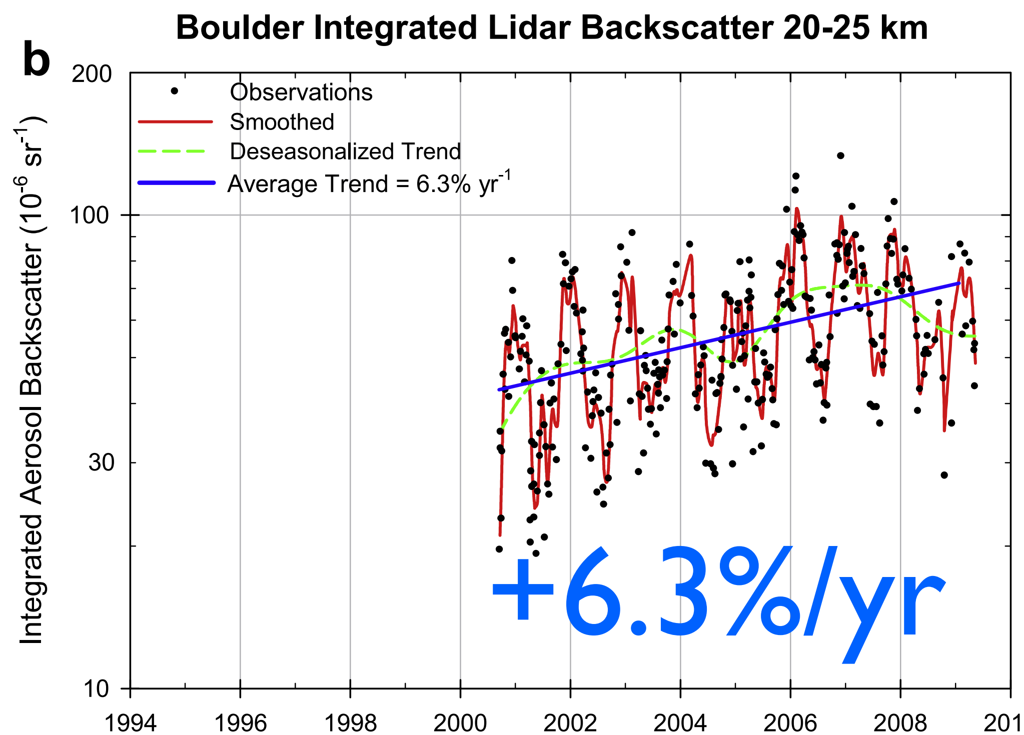
- The stratospheric aerosol layer has not been perturbed by a major volcano since Pinatubo in 1991.
- Recent lidar observations have shown trends in the amount of background aerosol.
- Hofmann at al. (2009) suggested a renewed modeling effort to understand the background layer.

- Here we start by comparing lidar data to a base run of WACCM coupled with CARMA to look at seasonal cycles in stratospheric aerosols.
- First study of its type with dust and sulfate aerosol model.

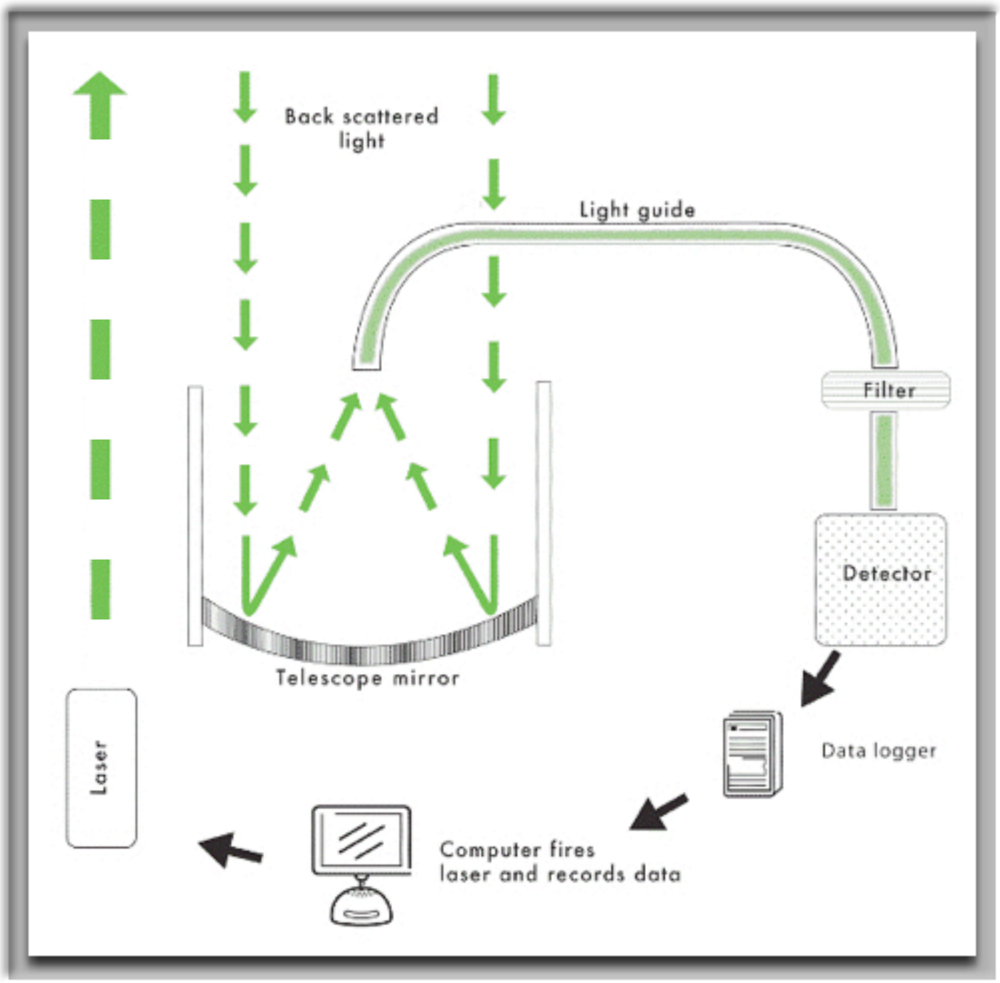
Motivation

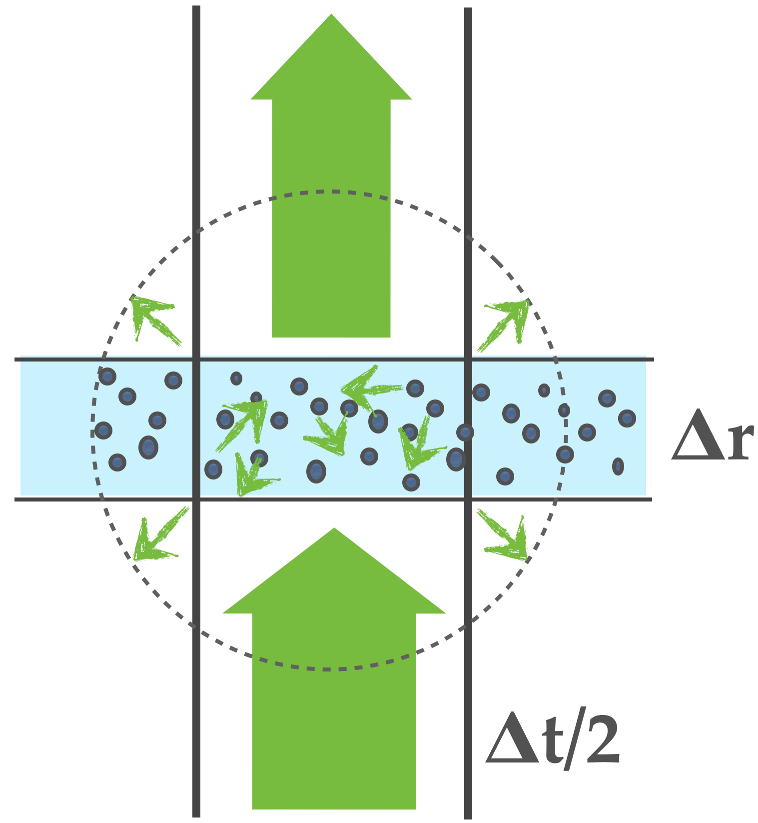
- Seasonal Cycles
  - What causes them?
- Trends
  - What is driving decadal trends?
    - Pollution?
    - Volcanoes?





Rayleigh/Mie LIDAR





$$N(\lambda, z) = N_L(\lambda)[\beta(\lambda, z)\Delta R]\frac{A}{z^2}exp[-2\int_0^z \alpha(\lambda, z')\,dz'][\eta(\lambda)G(\lambda, z)] + N_B(\lambda, z)$$

$$\beta_{Scatter}(\lambda, z) = \beta_{aerosol}(\lambda, z) + \beta_{molecule}(\lambda, z)$$

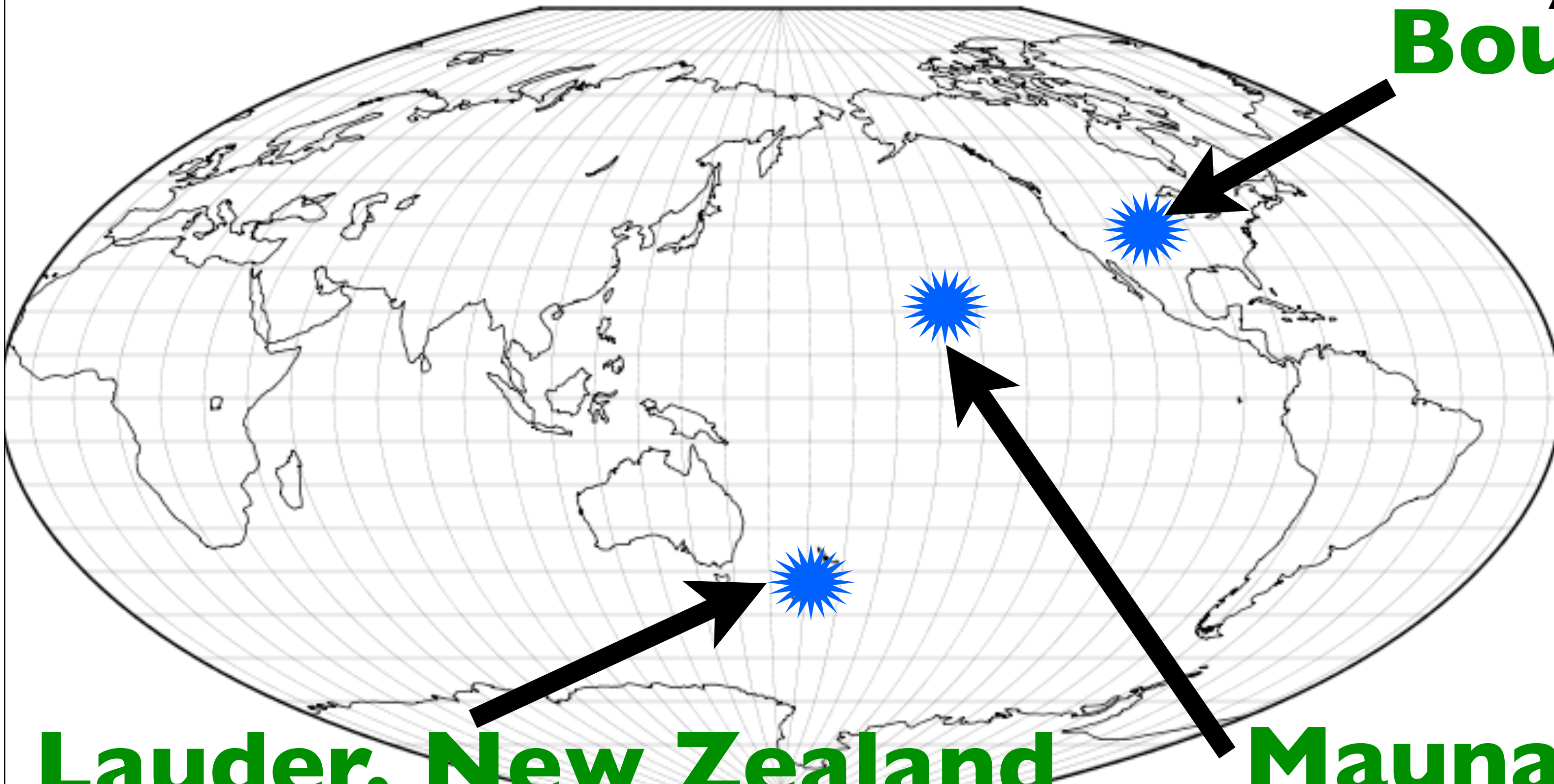
Backscatter

$$\beta(532nm, \pi, z) = \pi \int_0^\infty r^2 Q_\pi(\tilde{m}, x) n(r, z) dr$$

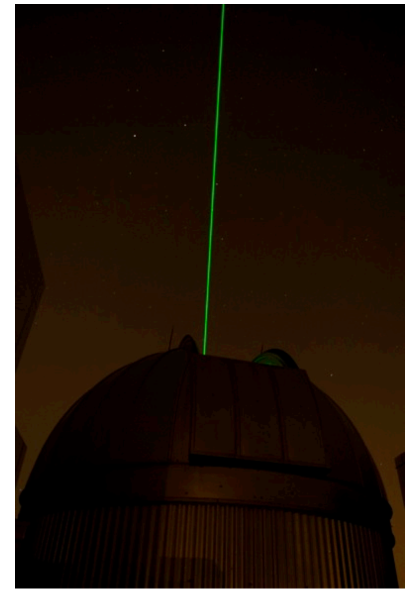
$$x = \frac{2\pi r}{\lambda}$$

- Backscatter equation depends on:
  - Particle Radius
  - Size distribution
  - Index of refraction
- Comes from lidar data by inverting lidar equation
- Model backscatter calculated directly from model output size distribution and assuming an index of refraction(allowed to vary with H2SO4 content)

Lidar Sites in this Study



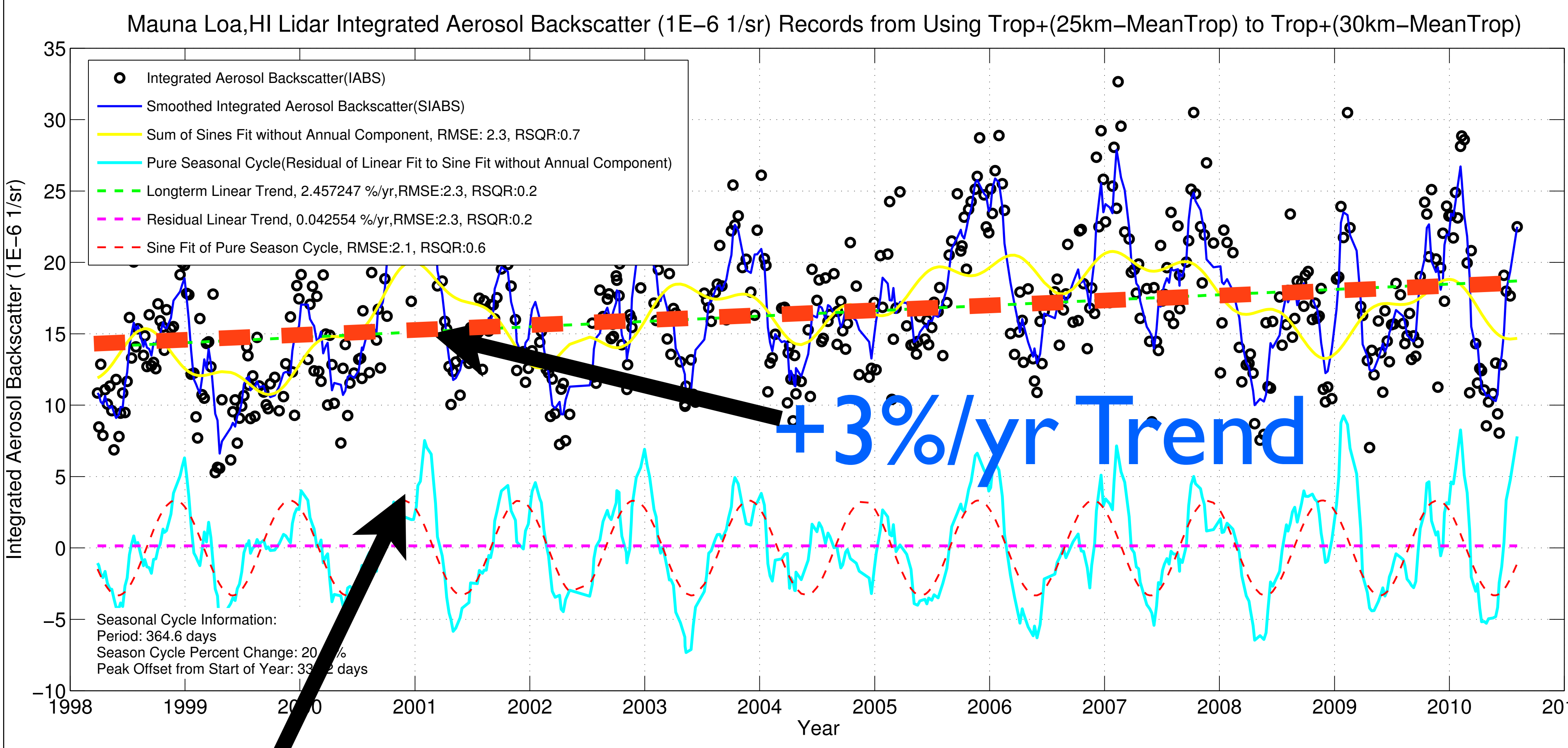
Boulder, CO



Lauder, New Zealand

Mauna Loa, HI

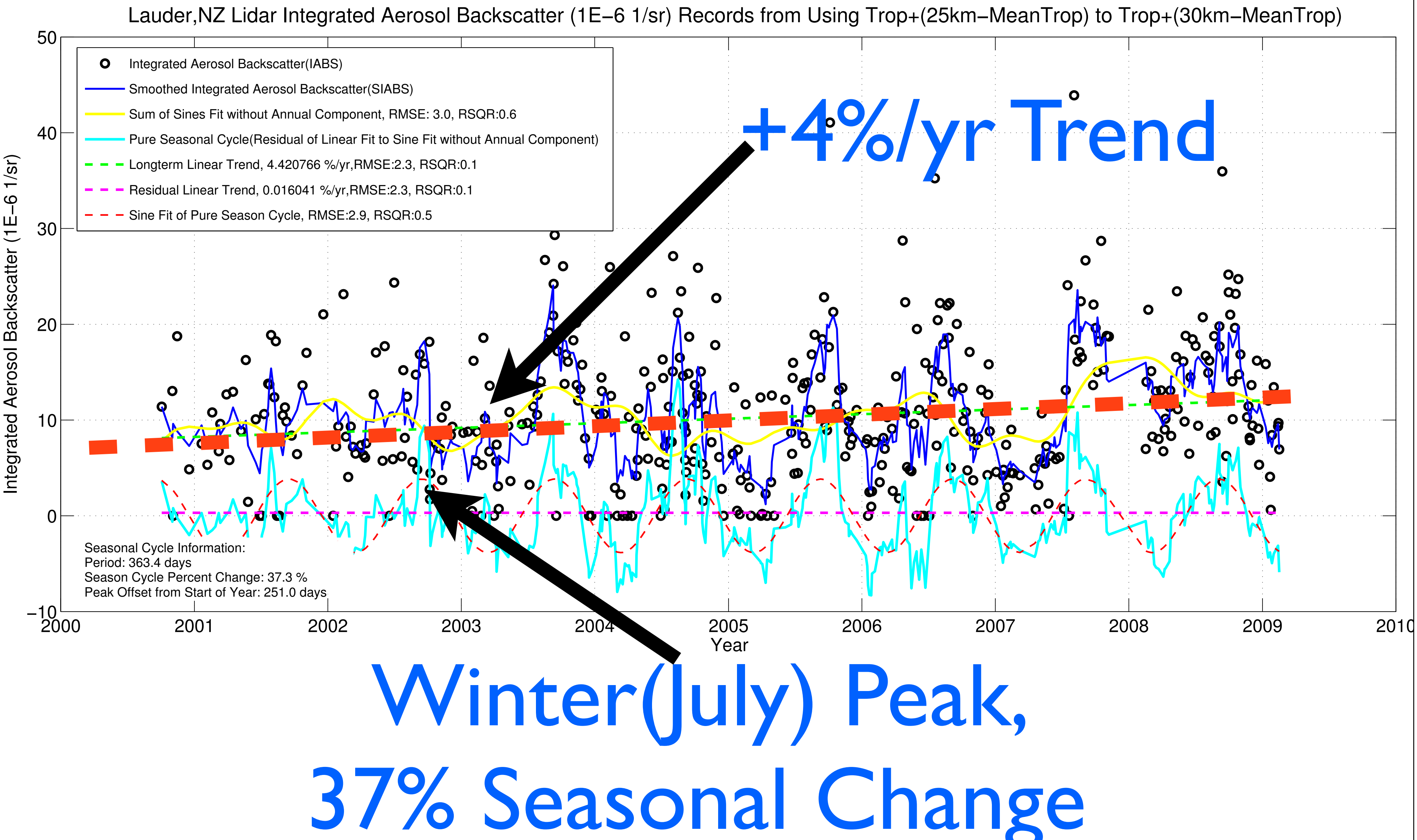
Lidar Records
Mauna Loa, HI
Integrated Backscatter from 25 to 30km



Winter Peak, 20.3% Seasonal Change

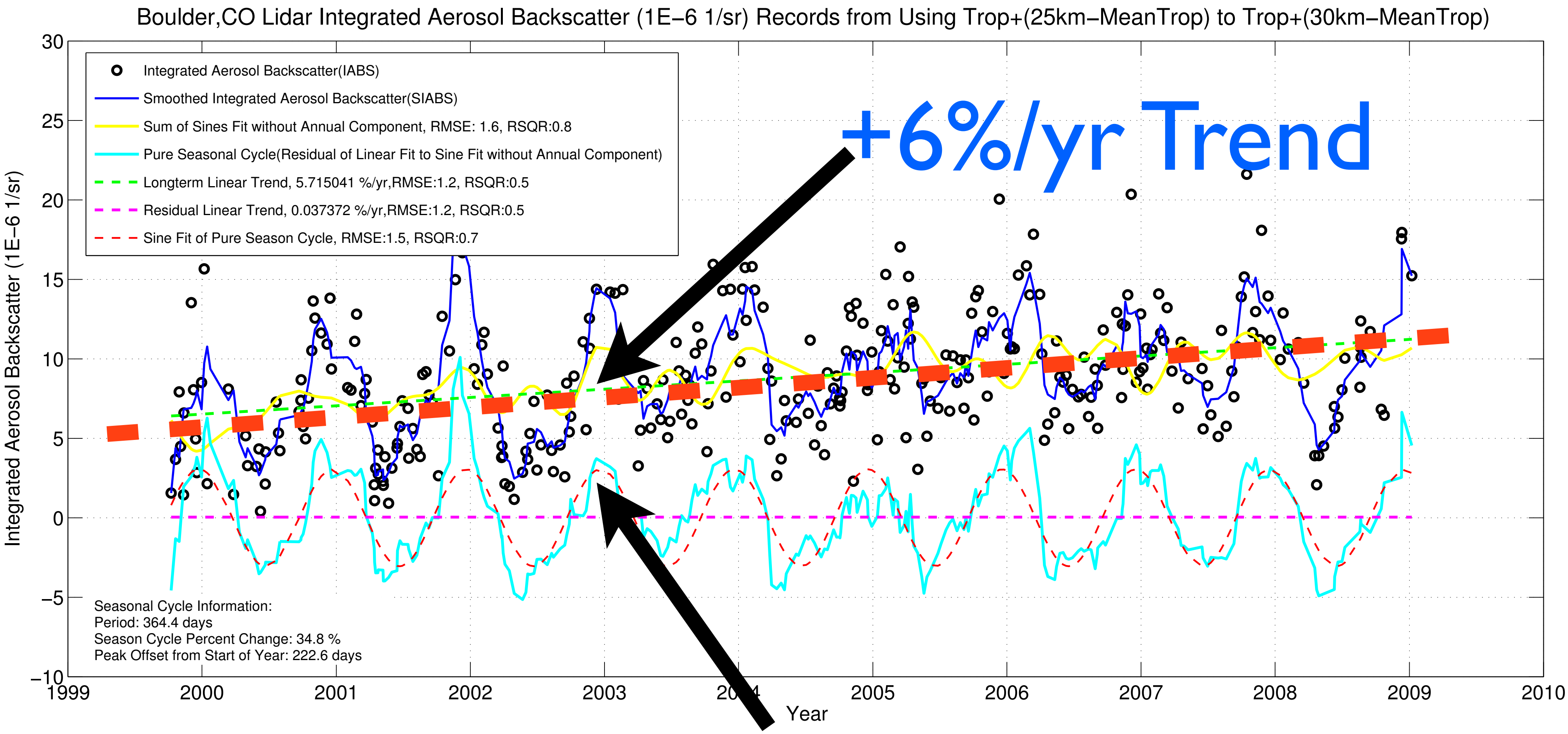
Lauder,NZ

Integrated Backscatter from 25 to 30km



Boulder,CO

Integrated Backscatter from 25 to 30km



Winter Peak, 35% Seasonal Change

WACCM Setup

- WACCM version 3.1.9
  - 4x5 degree resolution
  - 66 vertical levels
  - Model top near 140 km
  - Vertical spacing of 1-1.75km in the stratosphere
  - 25 year run, averaging last 10 years

WACCM Setup

- The main sulfur sources for stratospheric aerosols in the model are OCS and SO2.
- The OCS field is a lower boundary condition of 510 pptv.
- SO2 input is based on the work of Smith et al. (2011) and was adapted for use in WACCM by Dr. J. F. Lamarque.
- Emission data should be representative of background aerosol period.

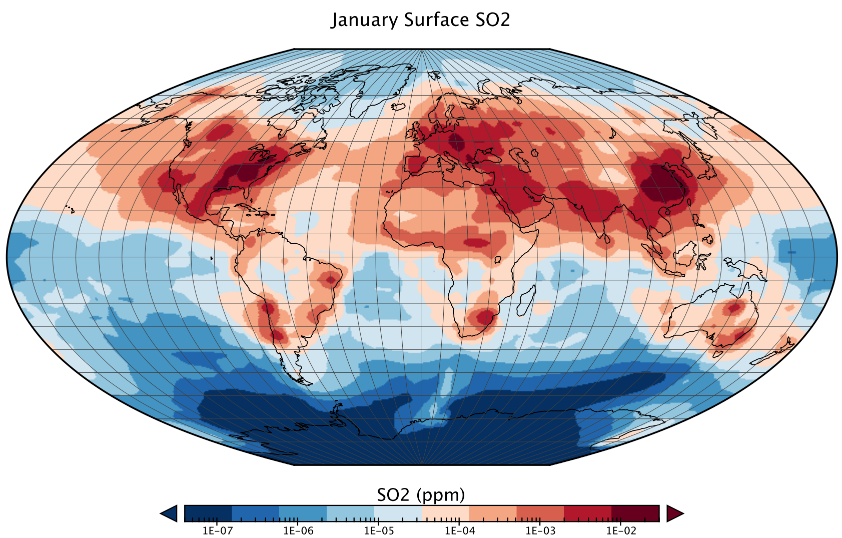


Figure 1.11: January SO_2 Surface Emissions

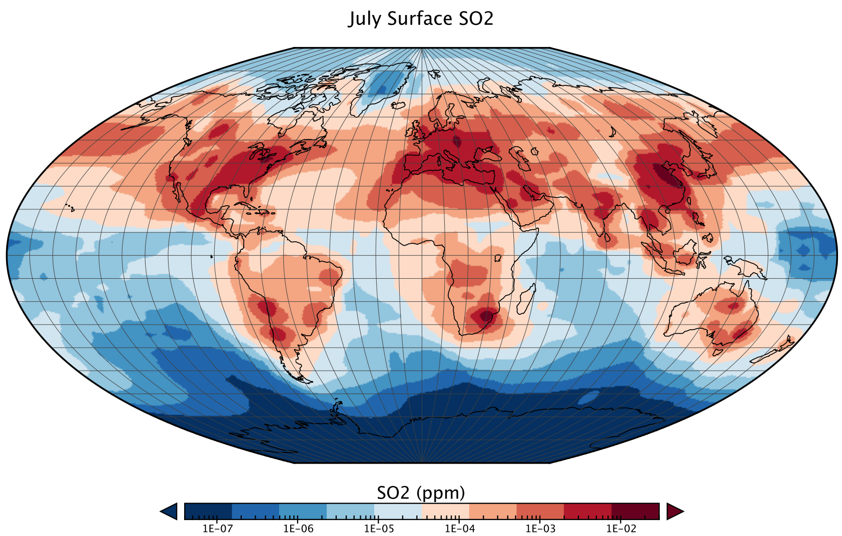
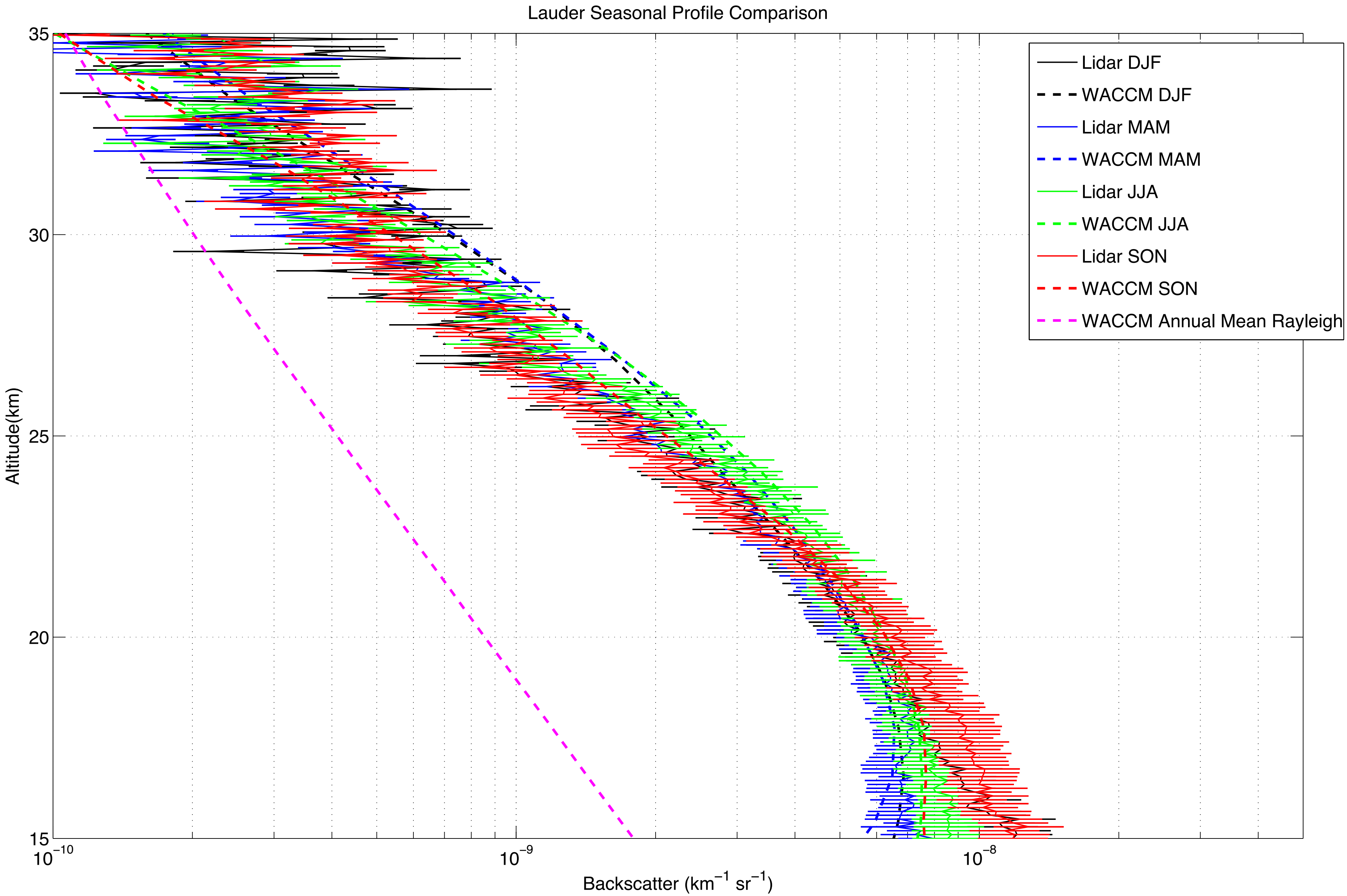


Figure 1.12: July SO_2 Surface Emissions

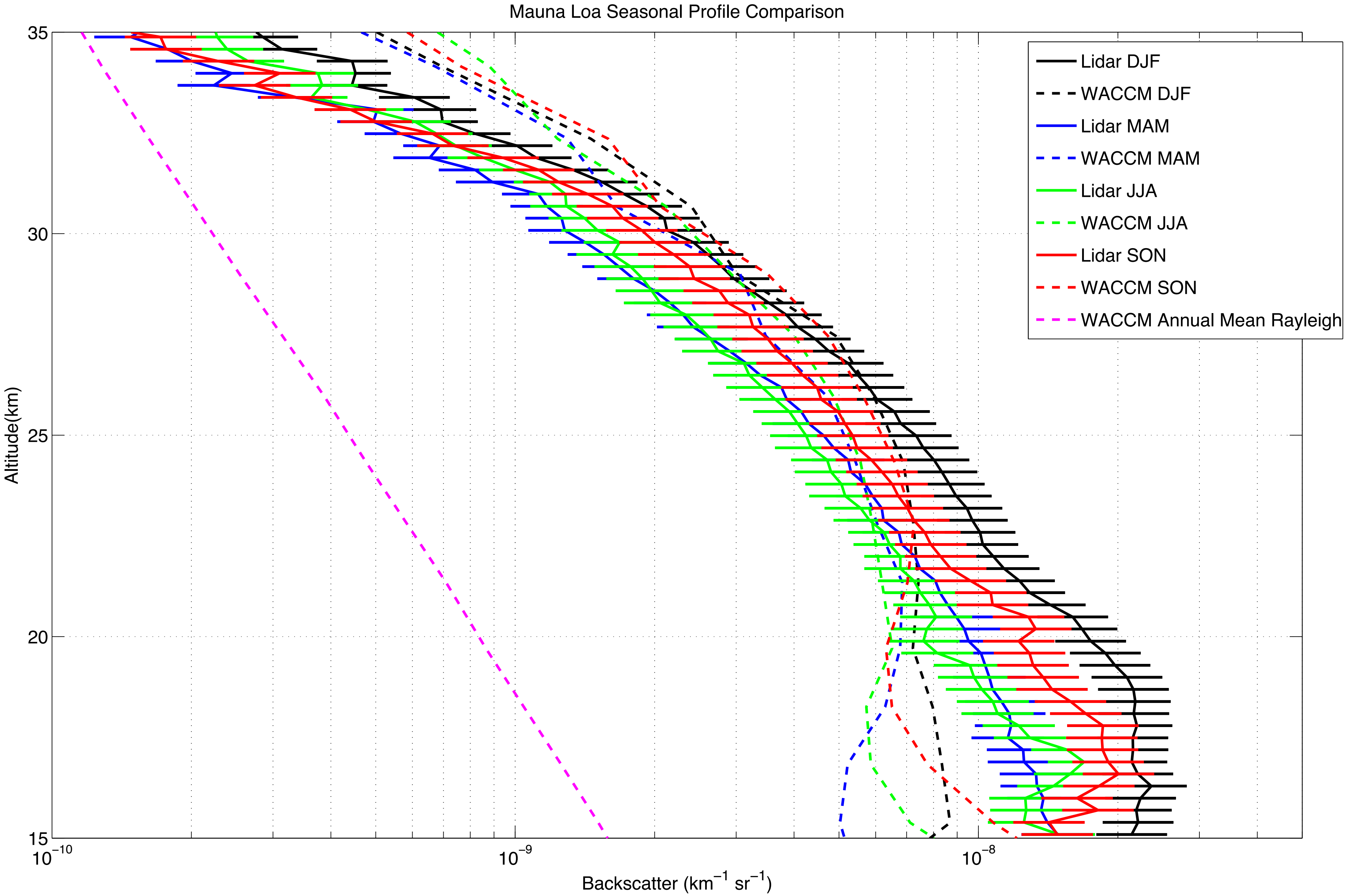
CARMA Setup

- Thirty-six bins (dry radii from 0.2nm to 1100nm) each for:
  - Pure sulfates(1)
  - Mixed sulfates(sulfate aerosols with dust cores)(2)
  - Meteoritic dust(3) (Similar to Bardeen et al 2008)
- Mass bins are set to be equal for all 3 groups of particles.
  - Thus, when a dust particle nucleates into the mixed sulfate group, there is no difference in mass to be accounted for by gas exchange.
- Fourth group of the dust cores keeps track of the dust cores after forming mixed sulfates.

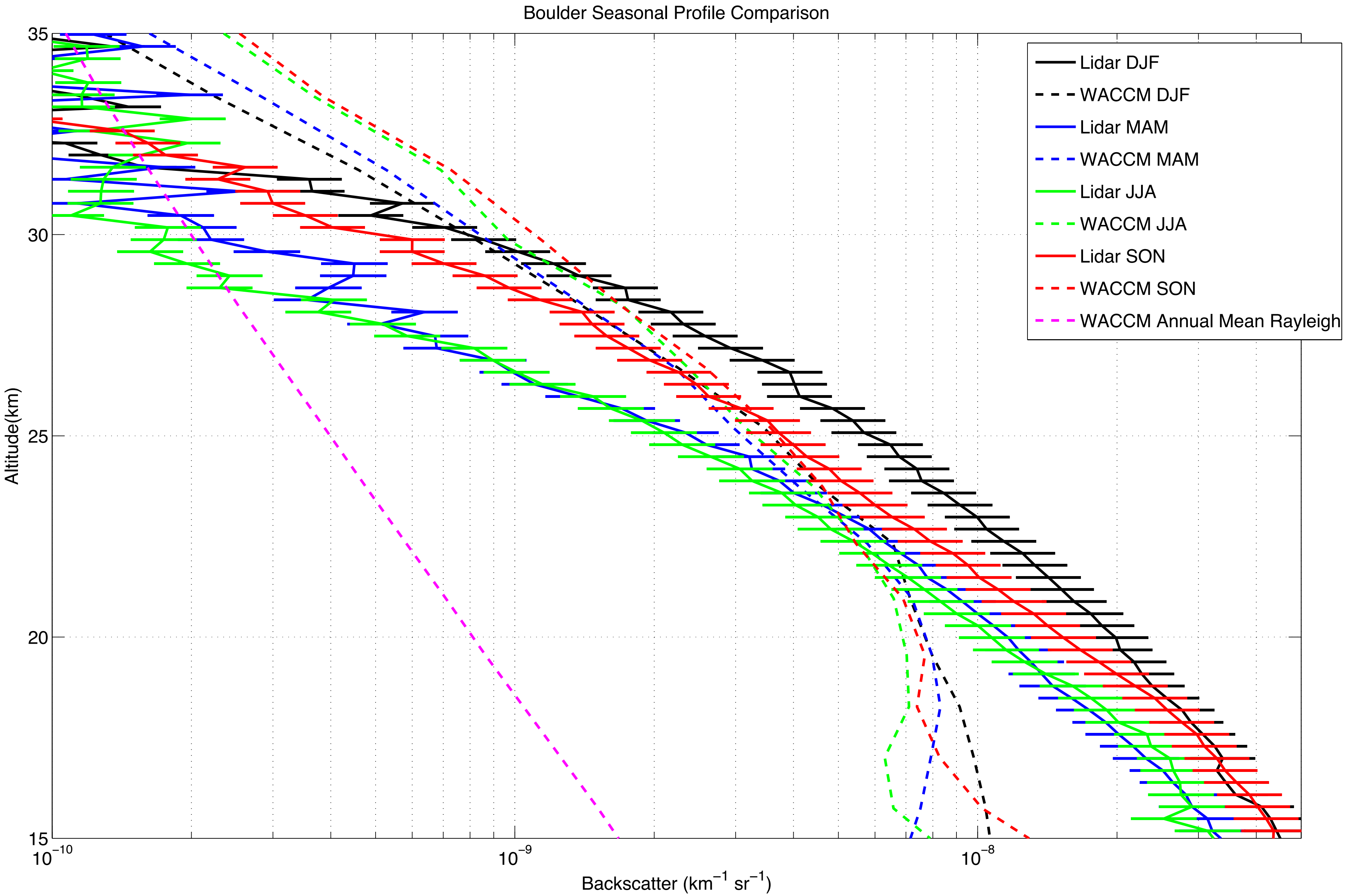
Lauder Comparison



Mauna Loa Comparison



Boulder Comparison

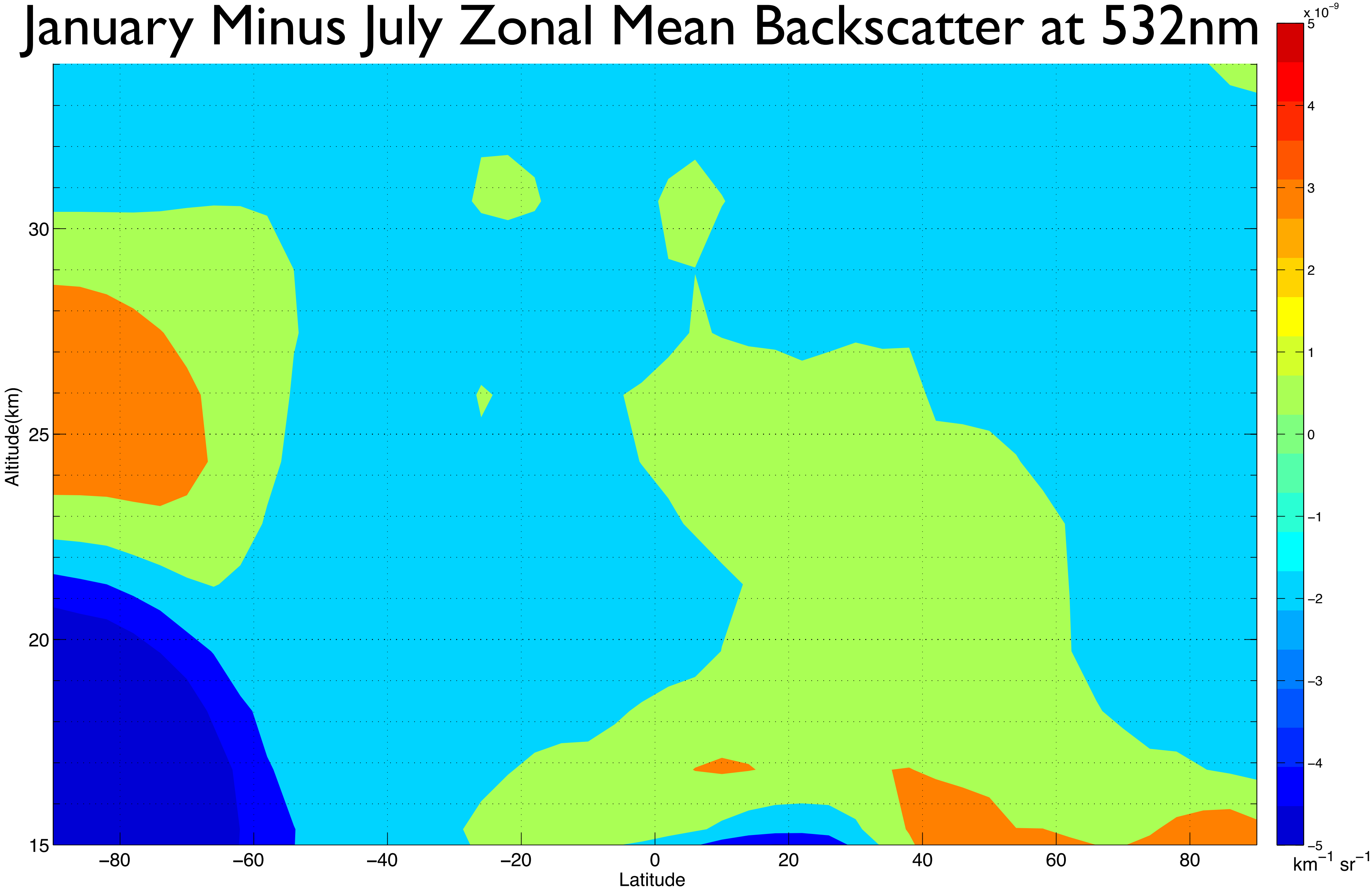


Peak to Peak Comparison

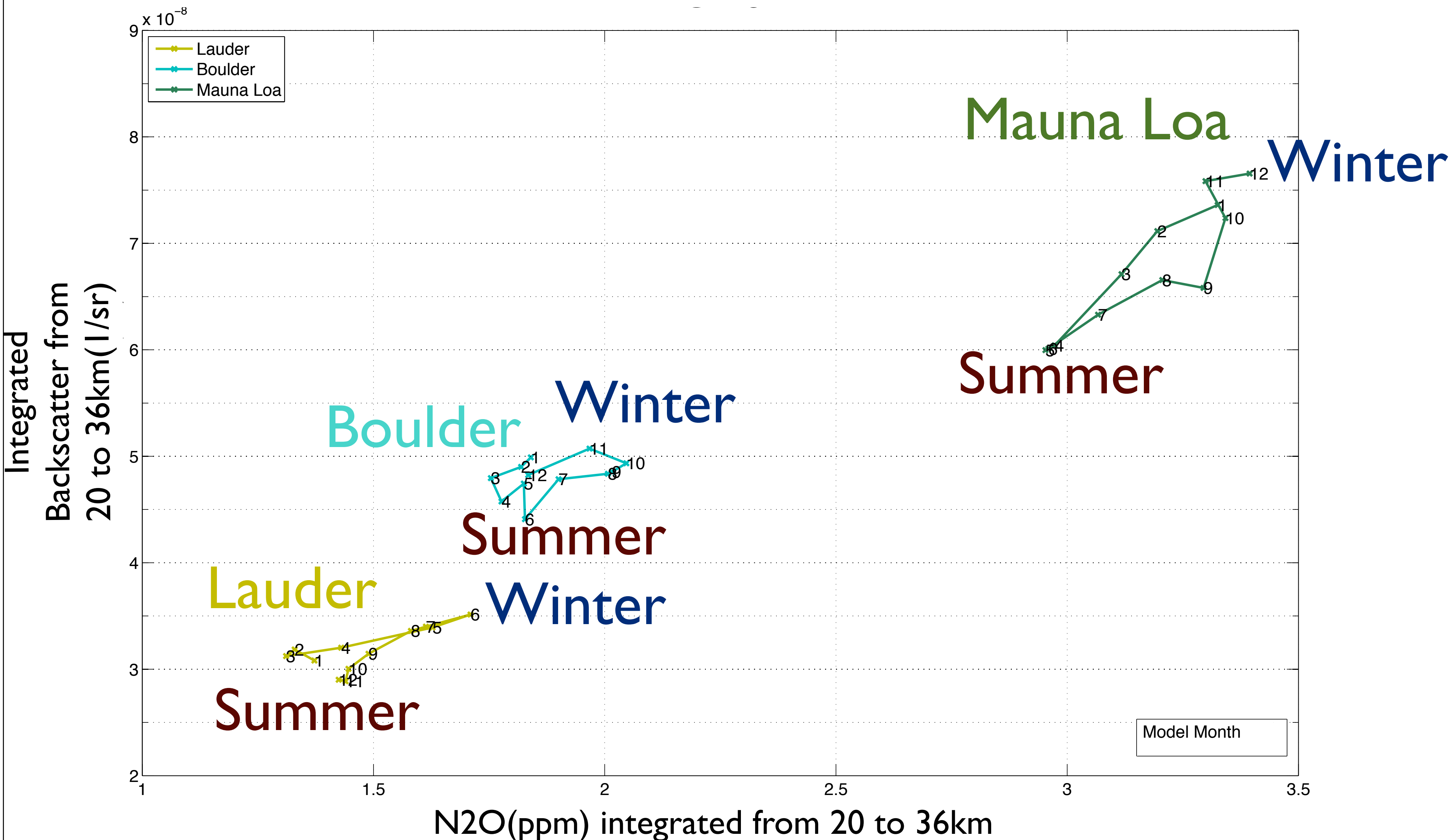
Backscatter Peak	Lidar Data	Model
Boulder	December	November
Mauna Loa	December	December
Lauder	July	June

Zonal Mean Seasonal Cycle

January Minus July Zonal Mean Backscatter at 532nm

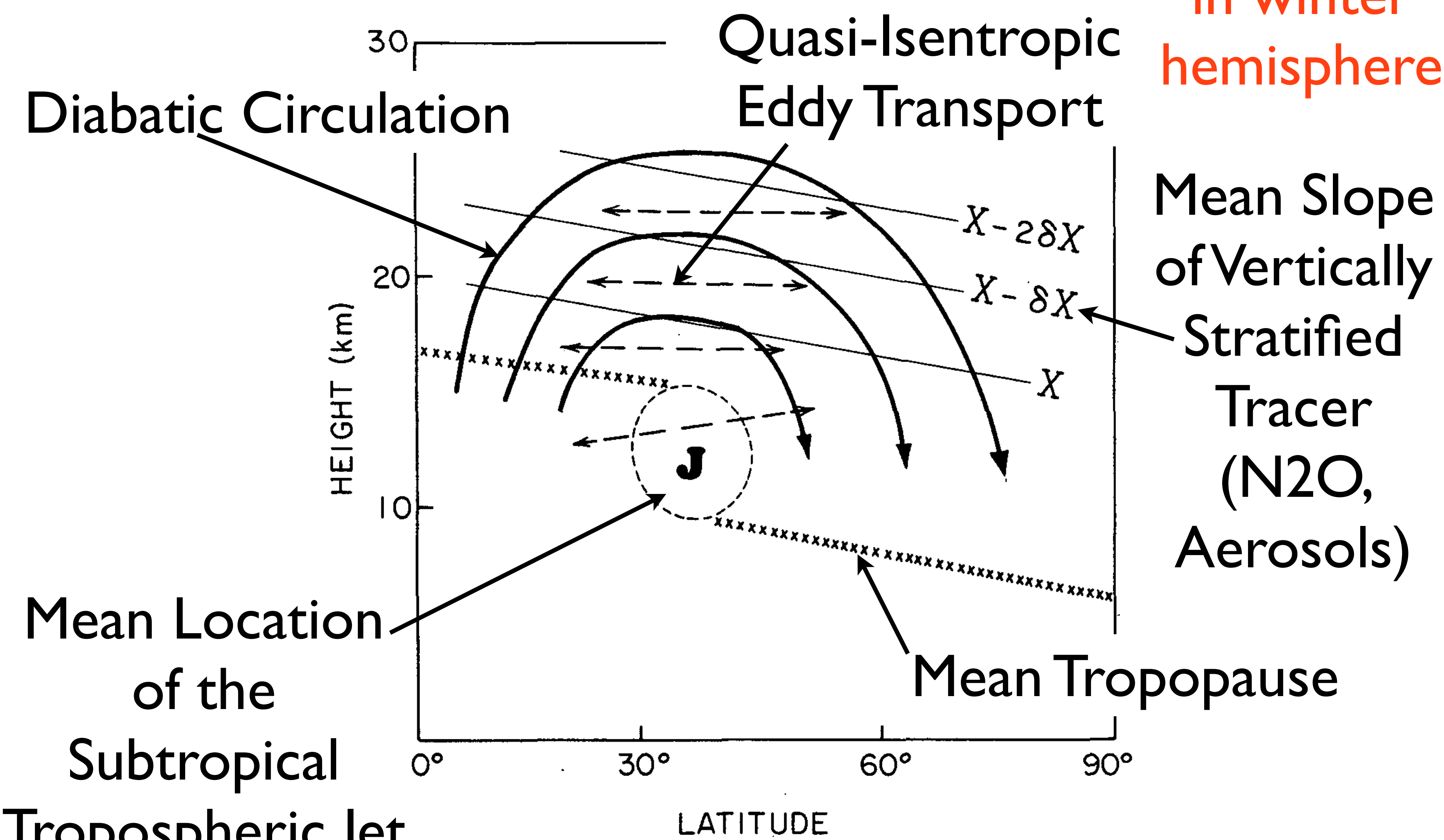


Correlation of Seasonal Cycle with N2O



Proposed Seasonal Cycle Mechanism

Strongest in winter hemisphere



Adapted from Holton (1986).

Summary of Results

- Lidar data and model agree well but work needs to be done on amplitude of seasonal cycle.

- Seasonal cycles are observed to be due to the seasonal shifts in quasi-isentropic transport created by planetary wave breaking.

- Interesting features in the poles and the lower stratosphere still need to be examined.

Future Work

- Will continue to make model better, especially in higher regions.

- Change input files to create trends in SO2 emissions and simulate small volcanoes to examine how these affect the aerosol layer.