ATMOS 5140
Lecture 8 – Chapter 7

- Atmospheric Transmission
  - Beer’s Law Review
  - Extinction, Scattering, and Absorption Coefficients
  - Extinction over a finite Path
  - Plane Parallel Approximation
  - Applications

Absorption

Review

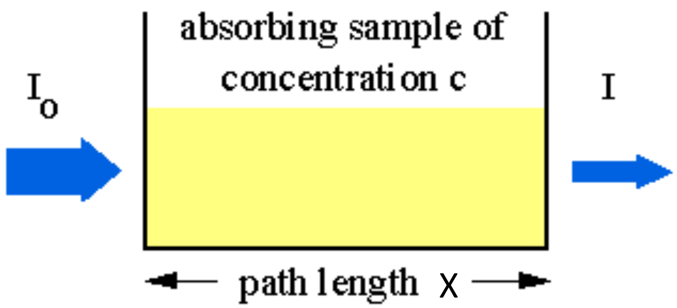
$$\beta_a = 4\pi n_i/\lambda$$

$\frac{1}{\beta_a}$= distance required for the wave's energy to be attenuated to e^{-1} (about 37%)

Beer’s Law

Review

$$I(x) = I_0\, e^{-\beta_a x}$$



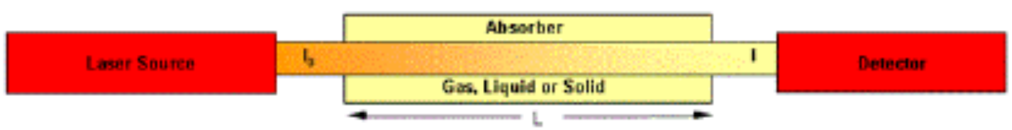
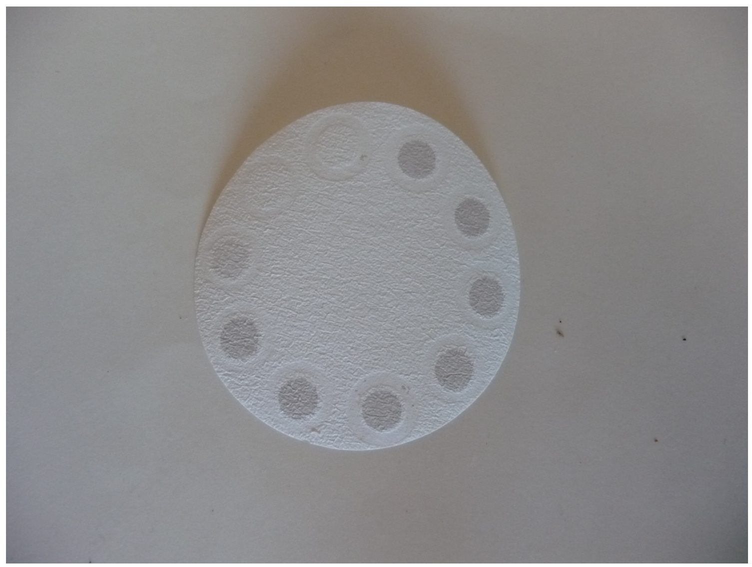


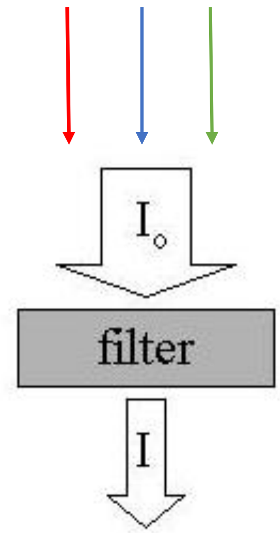
Figure 1: Laser absorption based on Beer-Lambert law.

Transmission

Review

$$t(x) \equiv \frac{I(x)}{I_0} = e^{-\beta_a x}$$

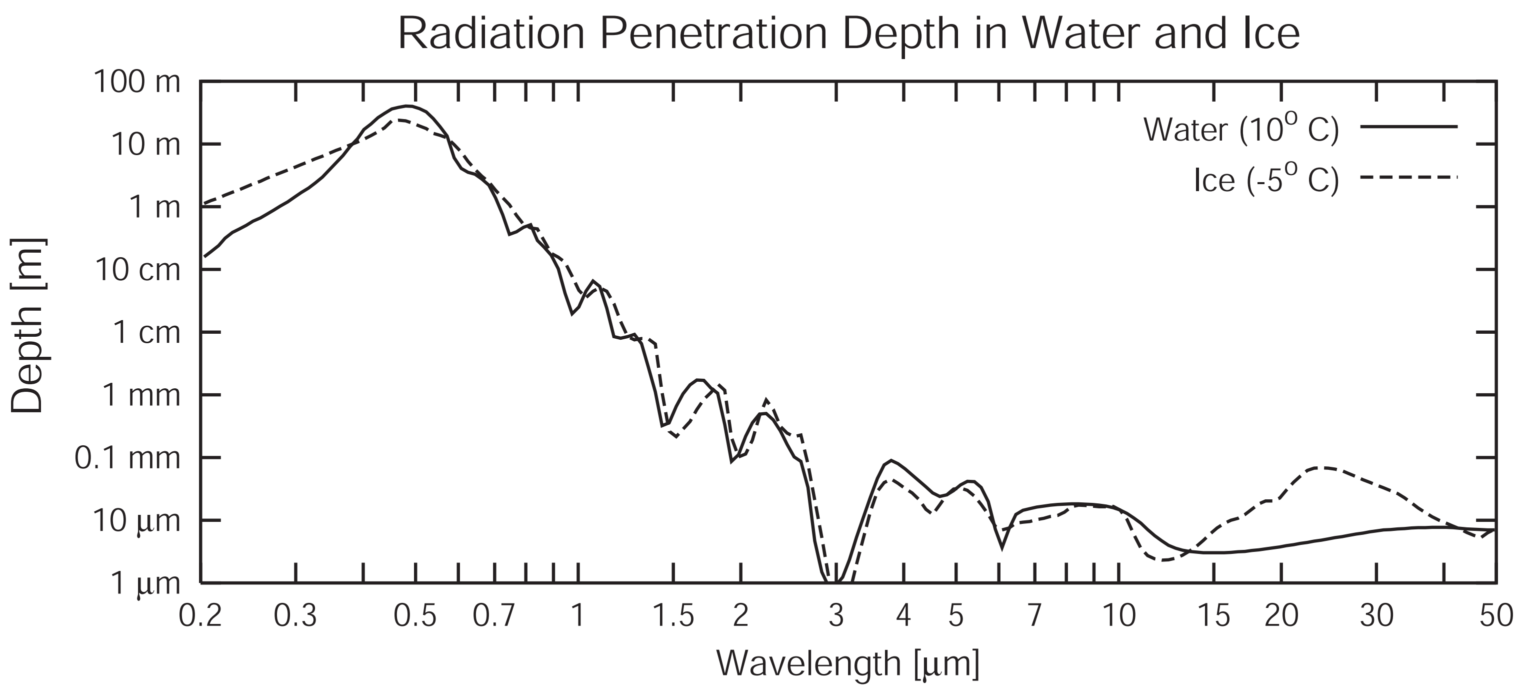




Penetration depth

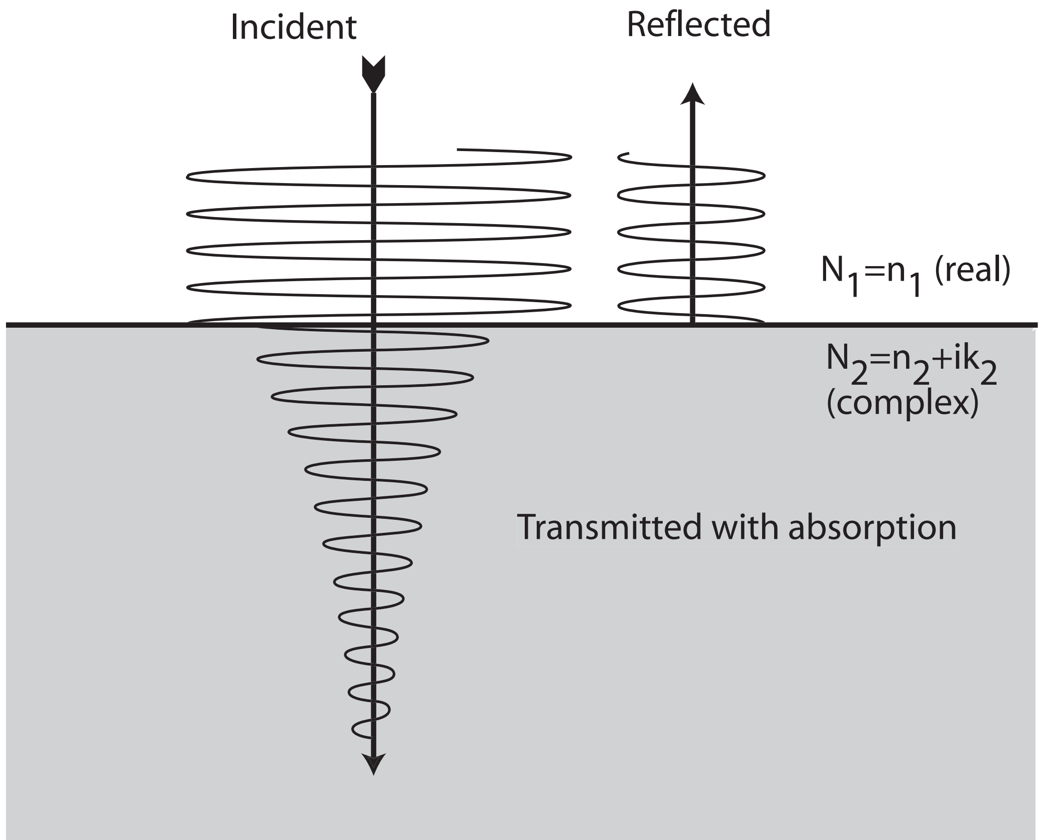
Review

$$D = \frac{1}{\beta_a} = \frac{\lambda}{4\pi n_i}$$



Transmission vs. Reflection

Review

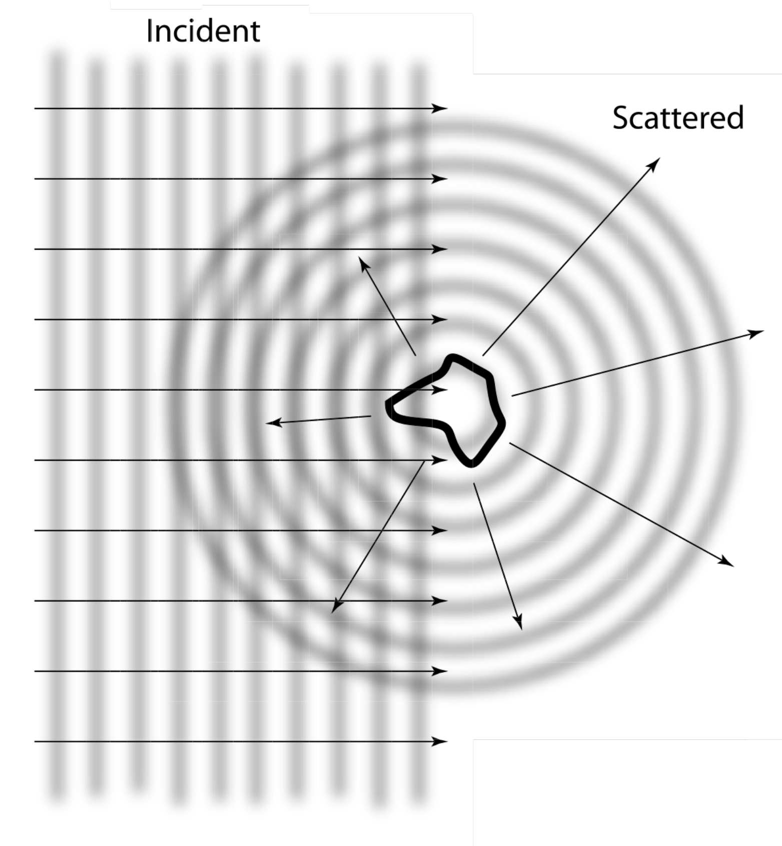


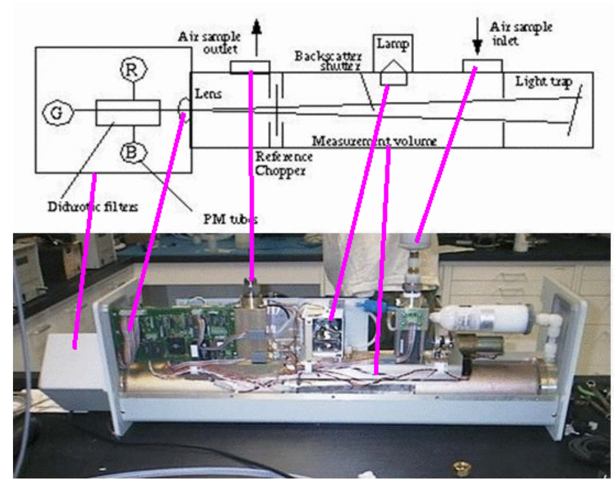
Attenuation of light

- **Absorption** - Conversion of the energy of the radiation to heat or chemical energy
- **Scattering** – redirection of the radiation out of the original direction of propagation

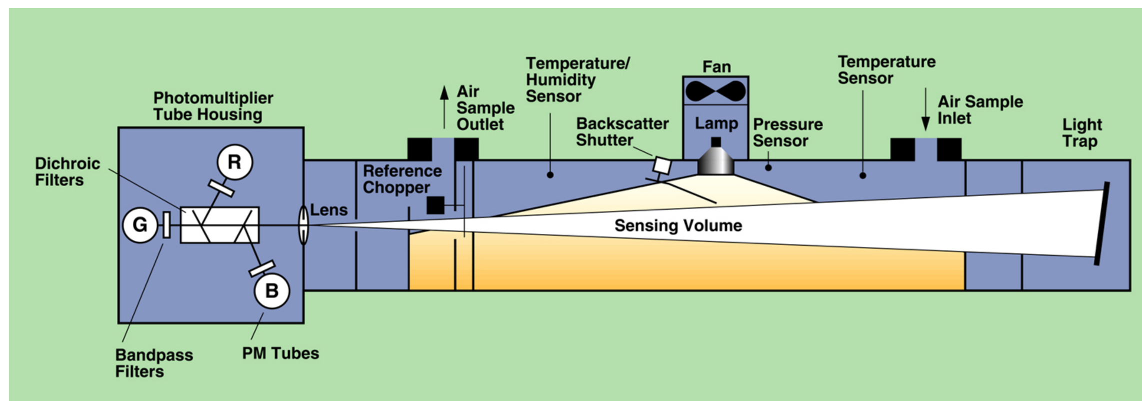
- **Extinction** is the SUM of Absorption and Scattering

Scattering of light by particle

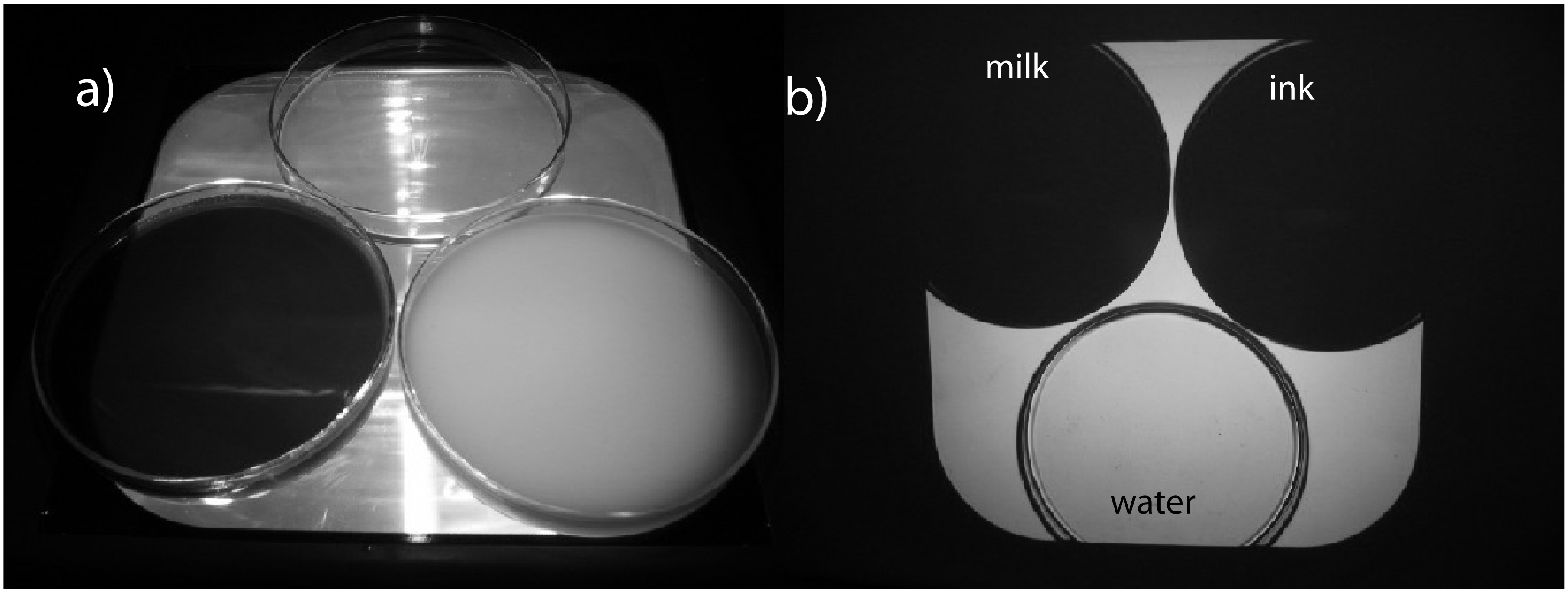




Measure with a Nephelometer



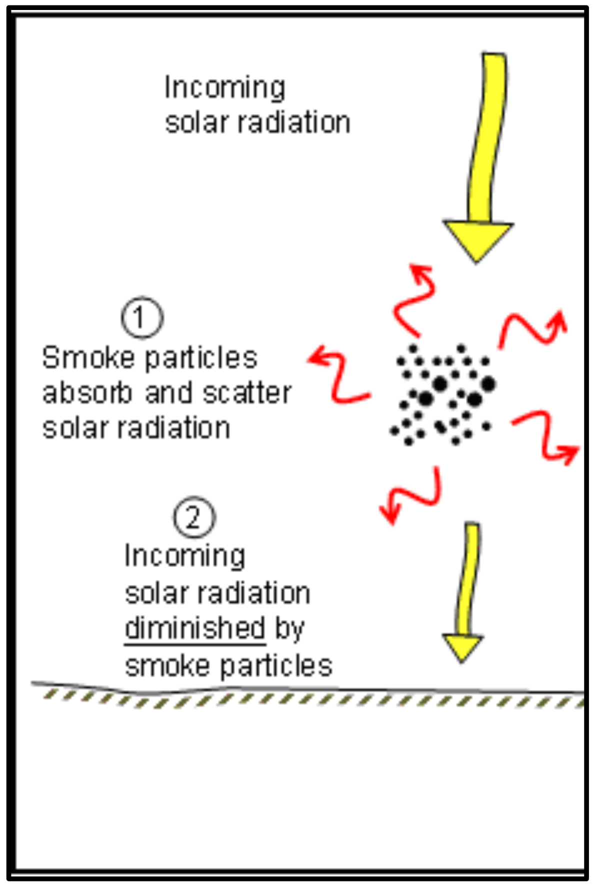
Absorption vs. Scattering



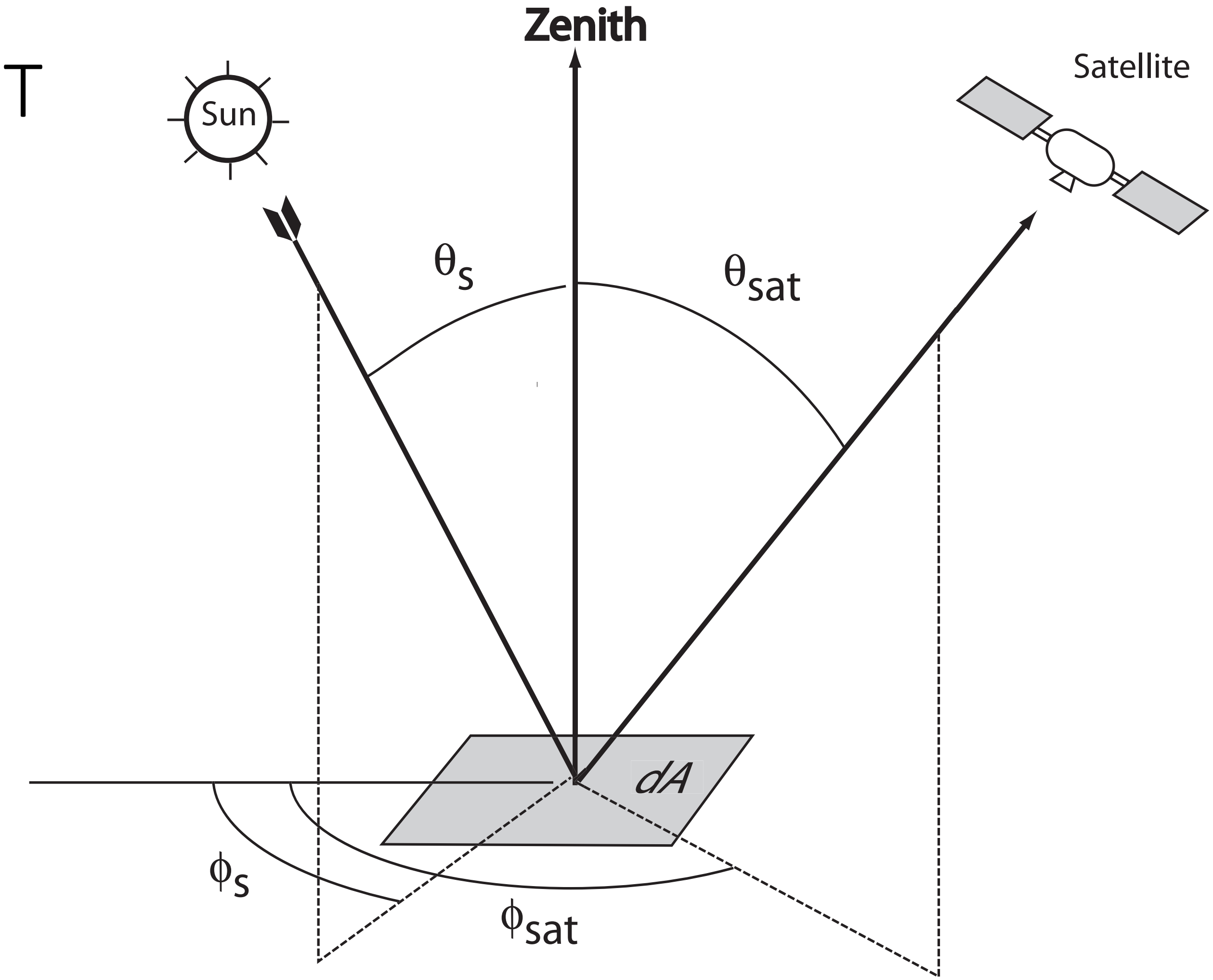
Demonstration of radiative extinction using an overhead projector (milk= scattering and ink=absorption)
Can test by

1. Looking at the side (see milk scatter light)
2. Testing with a thermometer - (ink will heat rise in temperature faster than milk)

Most aerosol particles both scatter and absorb



Problem 5.4
EXTRA CREDIT
5 points



Extinction, Absorption, and Scattering Coefficients

$$\beta_a = 4\pi n_i/\lambda$$

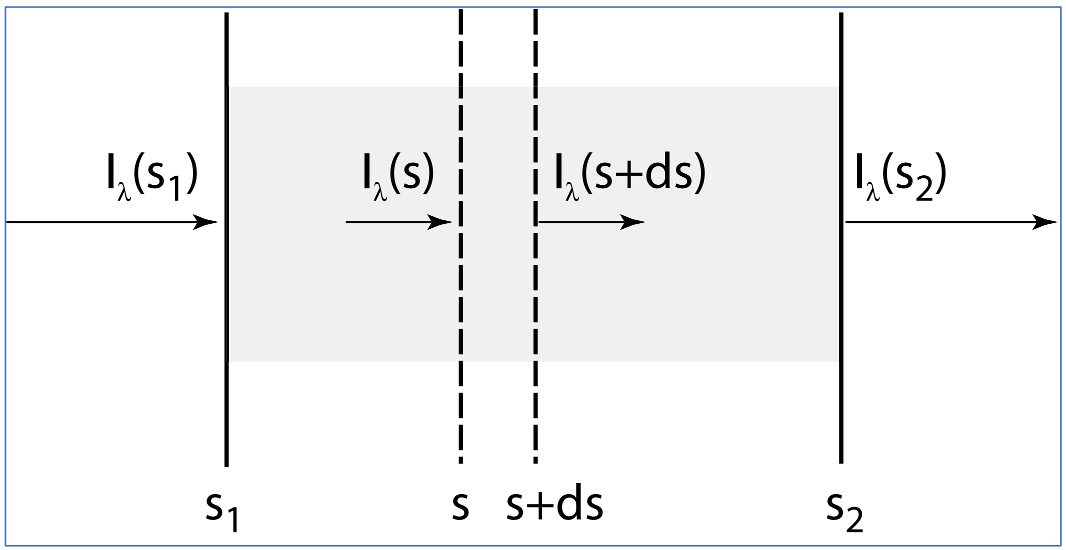
$$\beta_e = \beta_a + \beta_s$$

Single Scattering Albedo

$$\omega = \frac{\beta_s}{\beta_e} = \frac{\beta_s}{\beta_a + \beta_s}$$

Optical Path

- Optical depth or Optical thickness (measured vertically in the atmosphere)

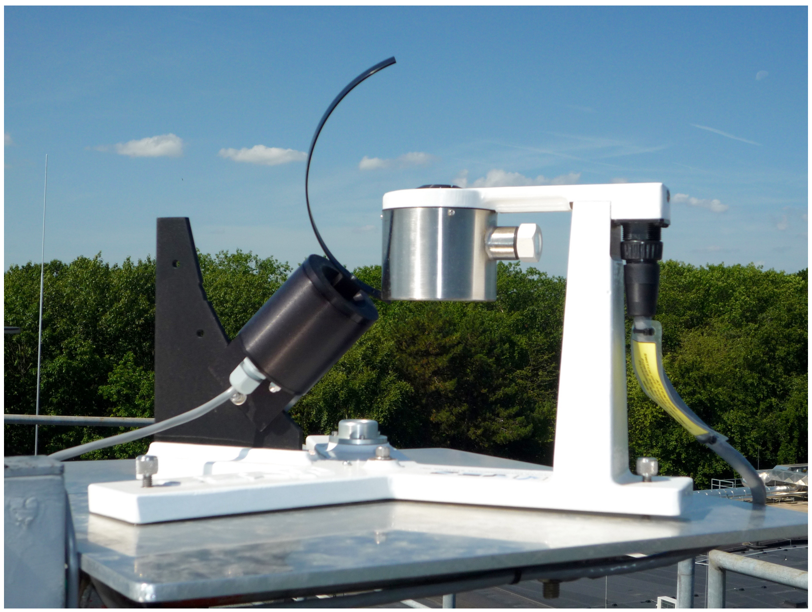


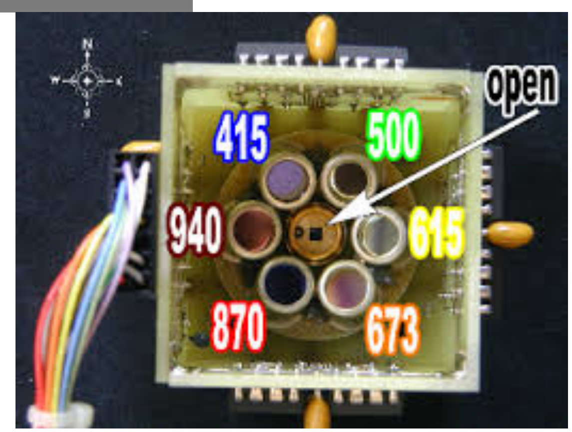
OPTICAL DEPTH

$$t(s_1, s_2) \equiv \frac{I_\lambda(s_2)}{I_\lambda(s_1)} = e^{-\beta_e(s_2 - s_1)} = e^{-\tau}$$

Measurement of optical depth

Processing - Measurements of Aerosol Optical Depth (AOD)





Recent Work using AOD data

A. G. Hallar et al.: Contributions of dust and biomass burning 13671

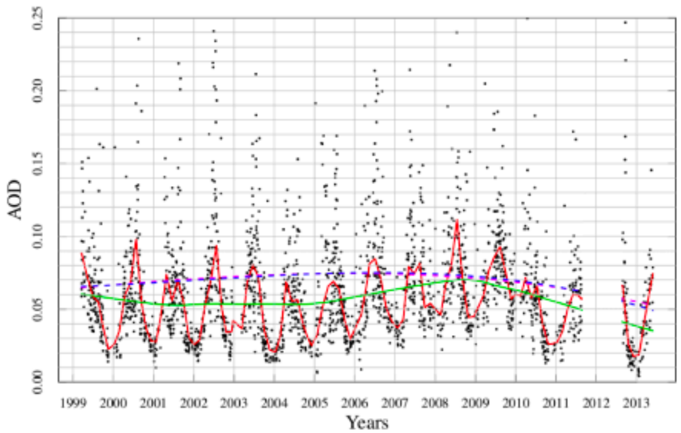
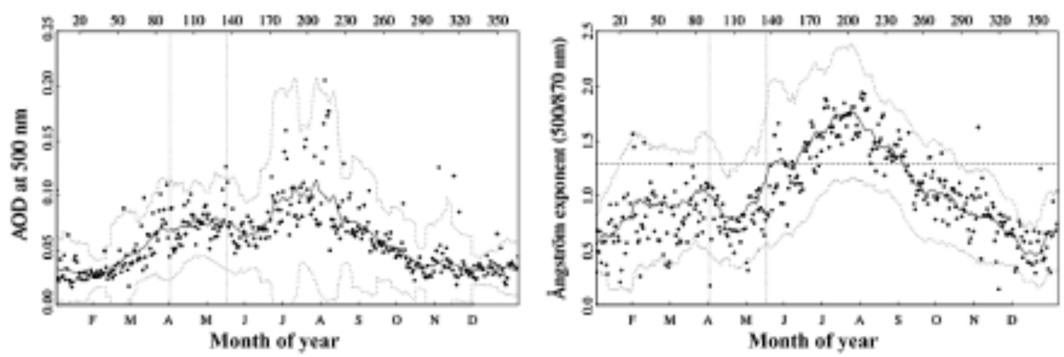


Figure 2. Black dots are 2252 daily averages of AOD at 500 nm. The red line is a loess fit with a 3-month window. The green line is a loess fit with a 5-year window. The blue dashed line is a least squares fit to a cubic polynomial. A year gap in the vis-MFRSR measurements occurred in 2011–2012. This interruption in vis-MFRSR operation was due to structural renovations at the SPL facility.



- Mass Extinction Coefficient
  - Extinction cross-section per unit mass

$$\beta_e = \rho k_e$$

Density

- Extinction Cross Section
  - Extinction cross section referenced to individual particles

$$\beta_e = N\sigma_e$$

Number of particles per cm^3

  - Extinction efficiency
    - Per the cross sectional area of the particle (A)

$$Q_e \equiv \frac{\sigma_e}{A}$$

- Mass Extinction Coefficient
  - Extinction cross-section per unit mass

$$\beta_e = \rho k_e$$

Density

- Extinction Cross Section
  - Extinction cross section referenced to individual particles

$$\beta_e = N\sigma_e$$

Number of particles per cm^3

  - Extinction efficiency
    - Per the cross sectional area of the particle (A)

$$Q_e \equiv \frac{\sigma_e}{A}$$

This also applies to Scattering and Absorption

$$\beta_a = \rho k_a$$

$$\beta_s = \rho k_s$$

$$\beta_a = N\sigma_a$$

$$\beta_s = N\sigma_s$$

$$Q_a \equiv \frac{\sigma_s}{A}$$

$$Q_s \equiv \frac{\sigma_s}{A}$$

Single Scatter Albedo

$$\omega = \frac{\beta_s}{\beta_e} = \frac{k_s}{k_e} = \frac{\sigma_s}{\sigma_e}$$

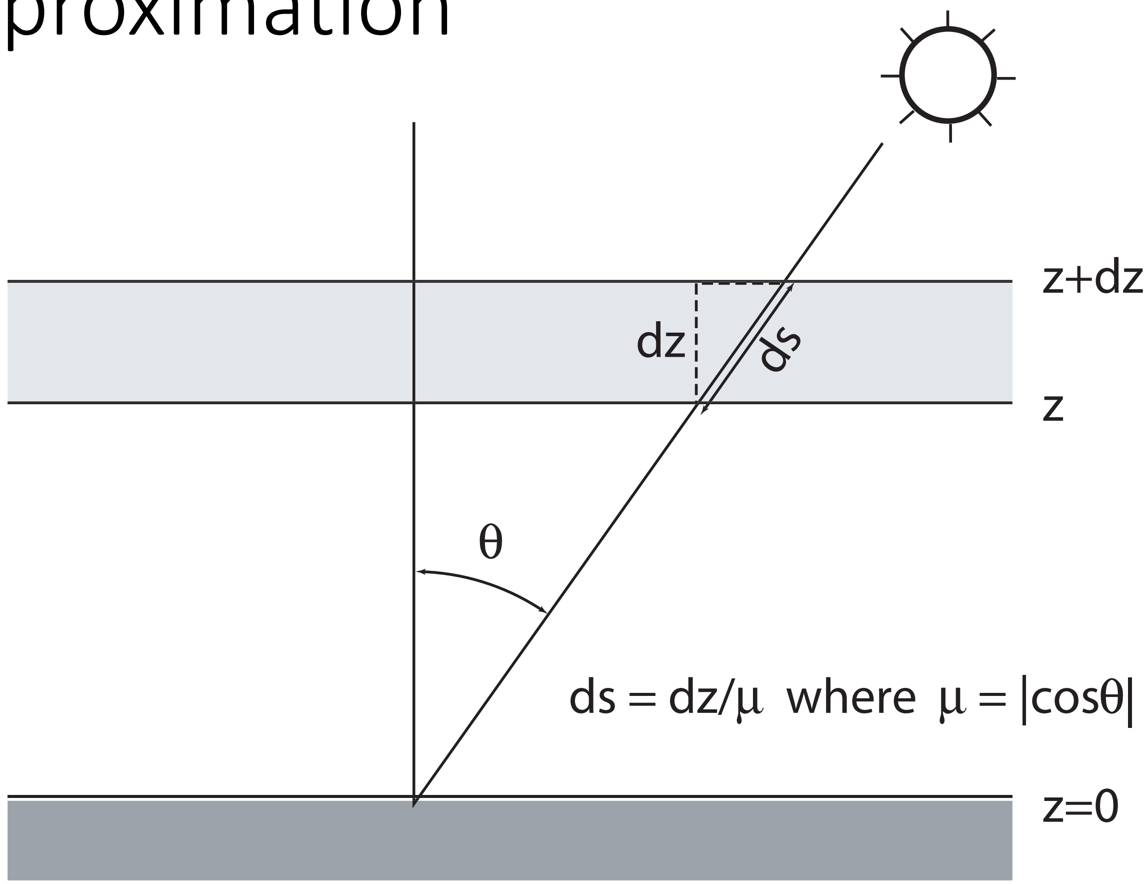
Plane Parallel Approximation

Rule of thumb for ignoring the curvature of the earth

$$H/_{\cos\theta} \lll R$$

Where:
H = height of atmosphere (~10 km)
R = radius of earth (~6373 km)

$$t(z_1, z_2) \equiv \frac{I_\lambda(z_2)}{I_\lambda(z_1)} = e^{-\beta_e(z_2 - z_1)} = e^{-\tau/\mu}$$



CO

N_2O

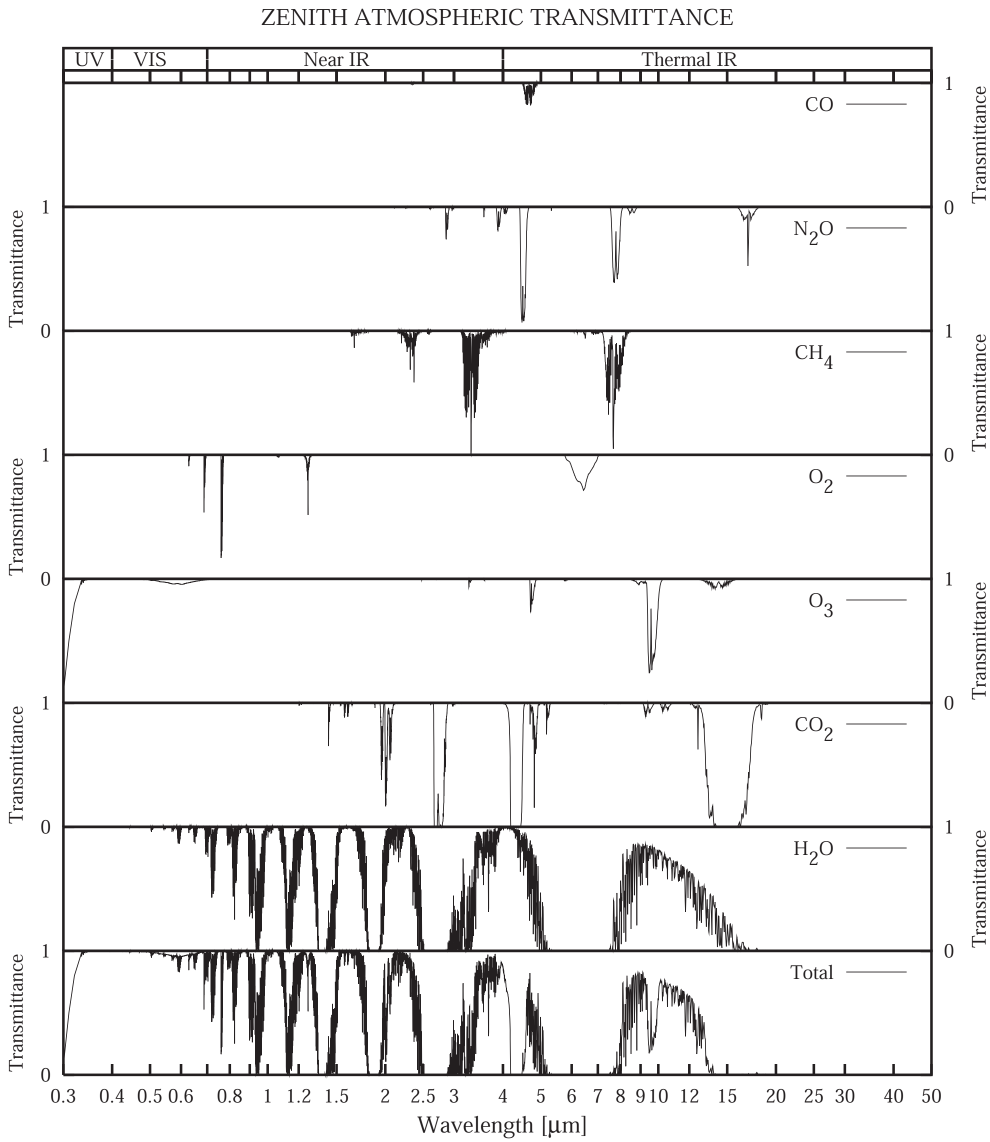
CH_4

O_2

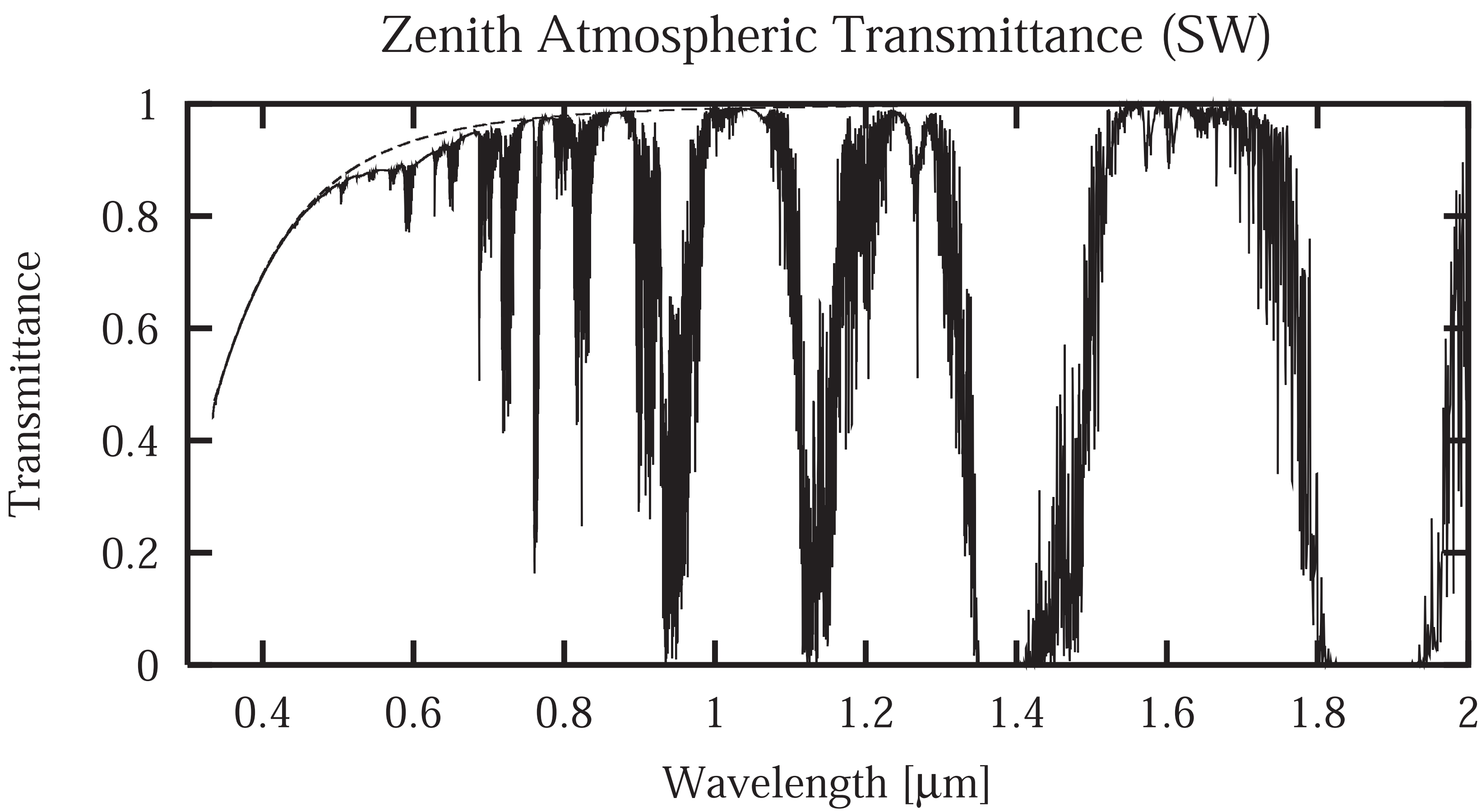
O_3

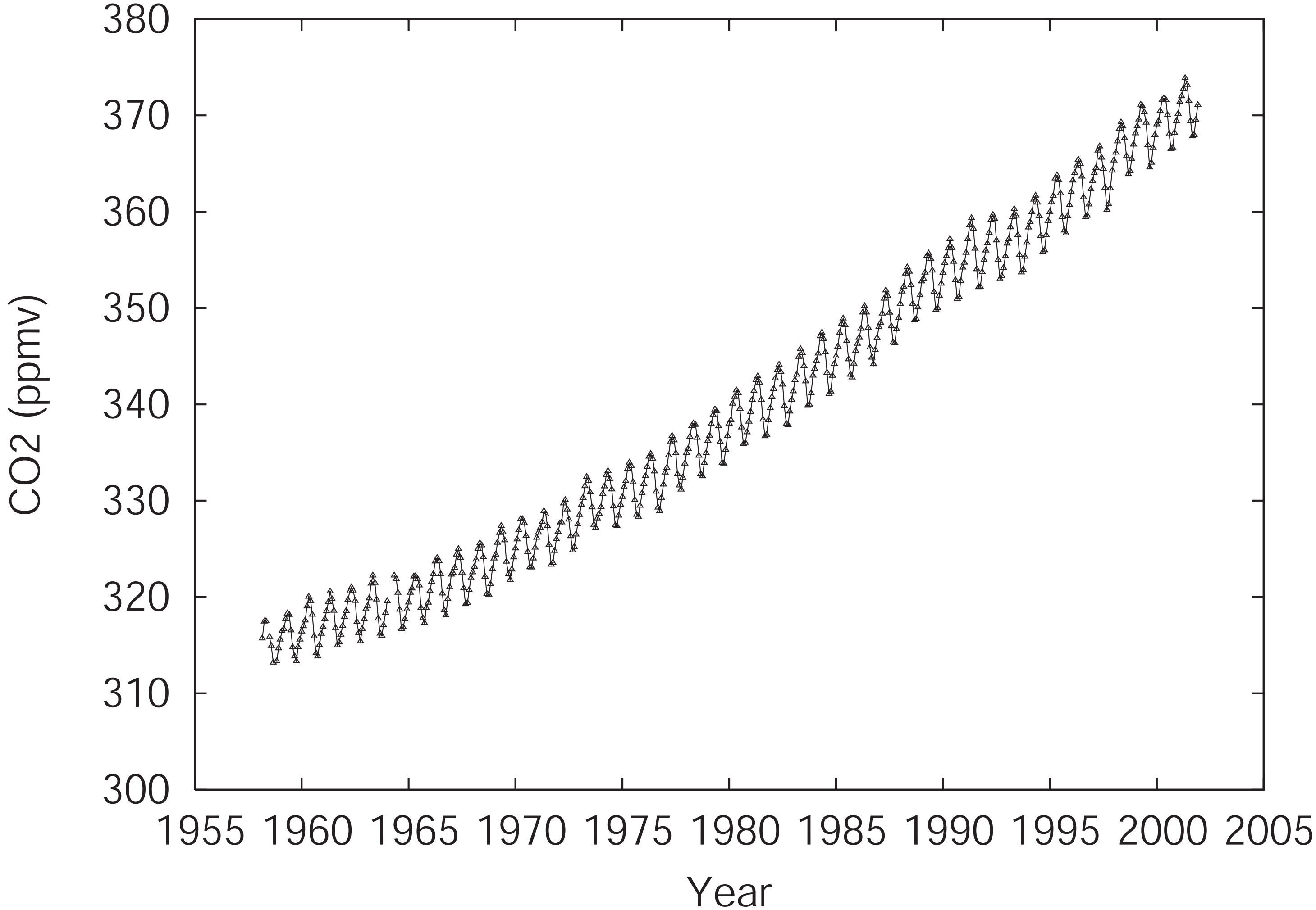
CO_2

H_2O



Zoom In


Zenith Atmospheric Transmittance (SW)
Transmittance
1
0.8
0.6
0.4
0.2
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Wavelength [µm]

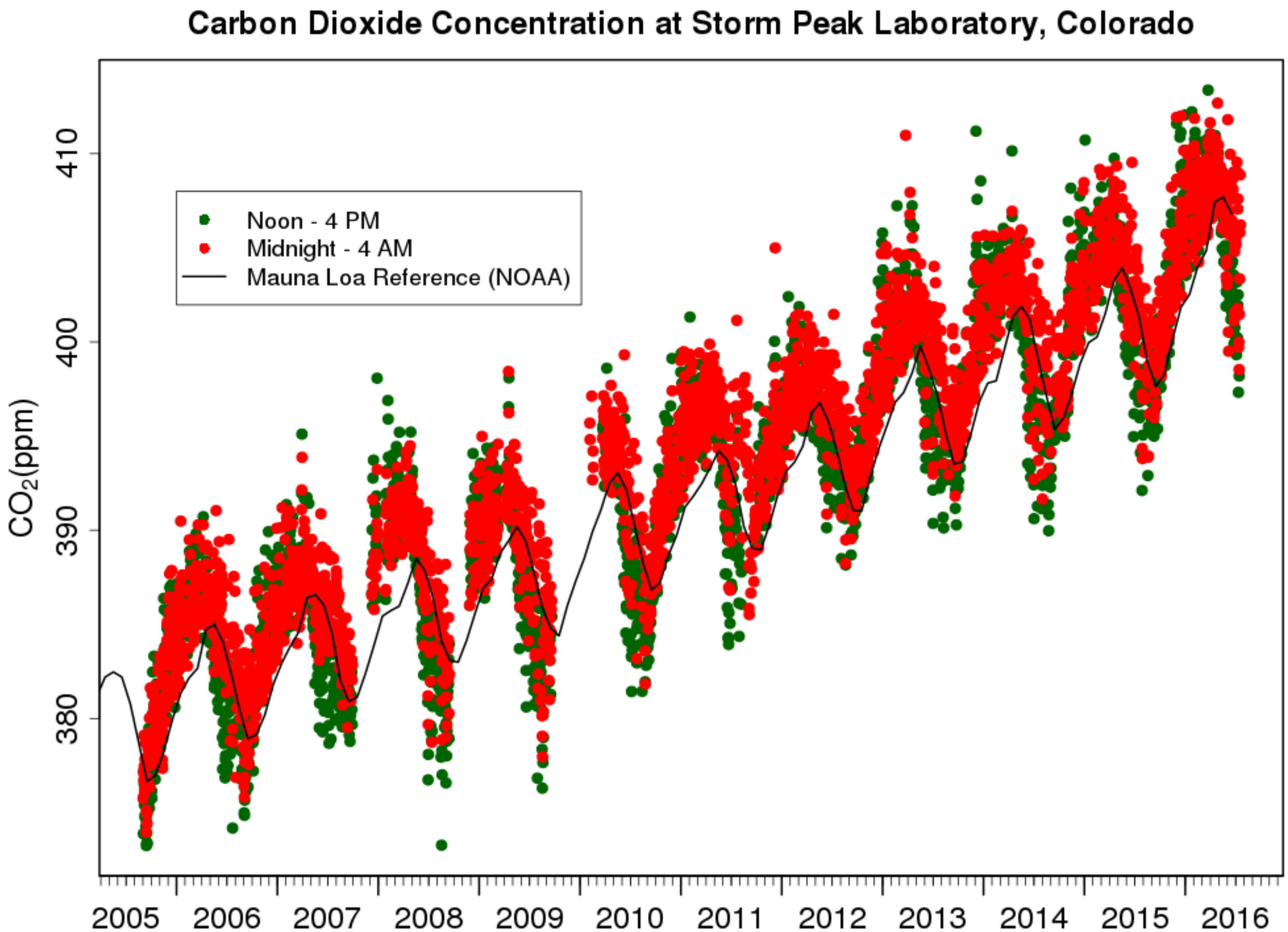


CO_2 This Morning
(March 27,2017)

406.42 ppm at
Mauna Loa

406.37 on the
roof of this
building.

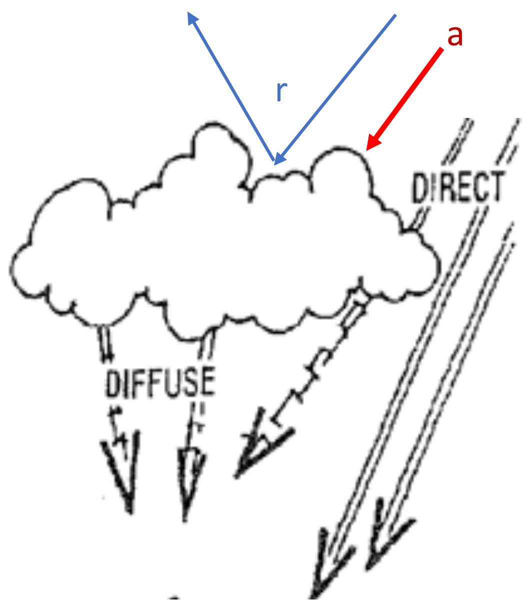
Quick walk down
the hall if time.



Carbon Dioxide Concentration at Storm Peak Laboratory, Colorado
Noon - 4 PM
Midnight - 4 AM
Mauna Loa Reference (NOAA)
CO_2(ppm)
410
400
390
380
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Transmittance of a Cloud Layer

$$t_{dir} + t_{diff} + r + a$$



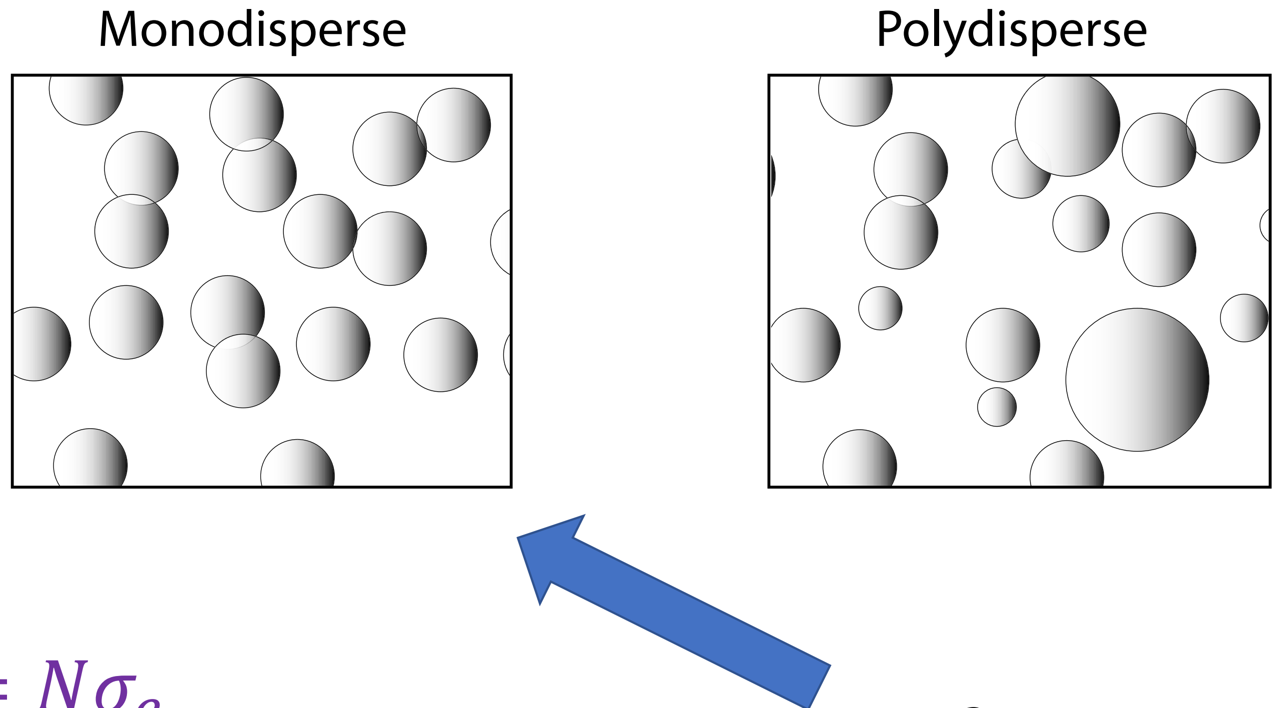
Total Transmittance

$$t = t_{dir} + t_{diff}$$

$$1 = t + r + a$$

$$t_{dir} = e^{-\tau * \mu}$$

*Indicated total optical thickness



$$\beta_e = N\sigma_e$$

$$Q_e \equiv \frac{\sigma_e}{A}$$

$$\beta_e = NQ_eA$$

$$\beta_e = NQ_e\pi r^2$$

$$\beta_e = \rho_w k_e = \rho_l k_e N\frac{4}{3}\pi r^3$$

Optical Thickness of Cloud

$$\tau^* = \int_{zbottom}^{ztop} \beta_e(z)dz = \int_{zbottom}^{ztop} k_e \rho_w(z)dz$$

Role of Cloud Condensation Nuclei