AEROSOL Particles-What’s all the fuss?

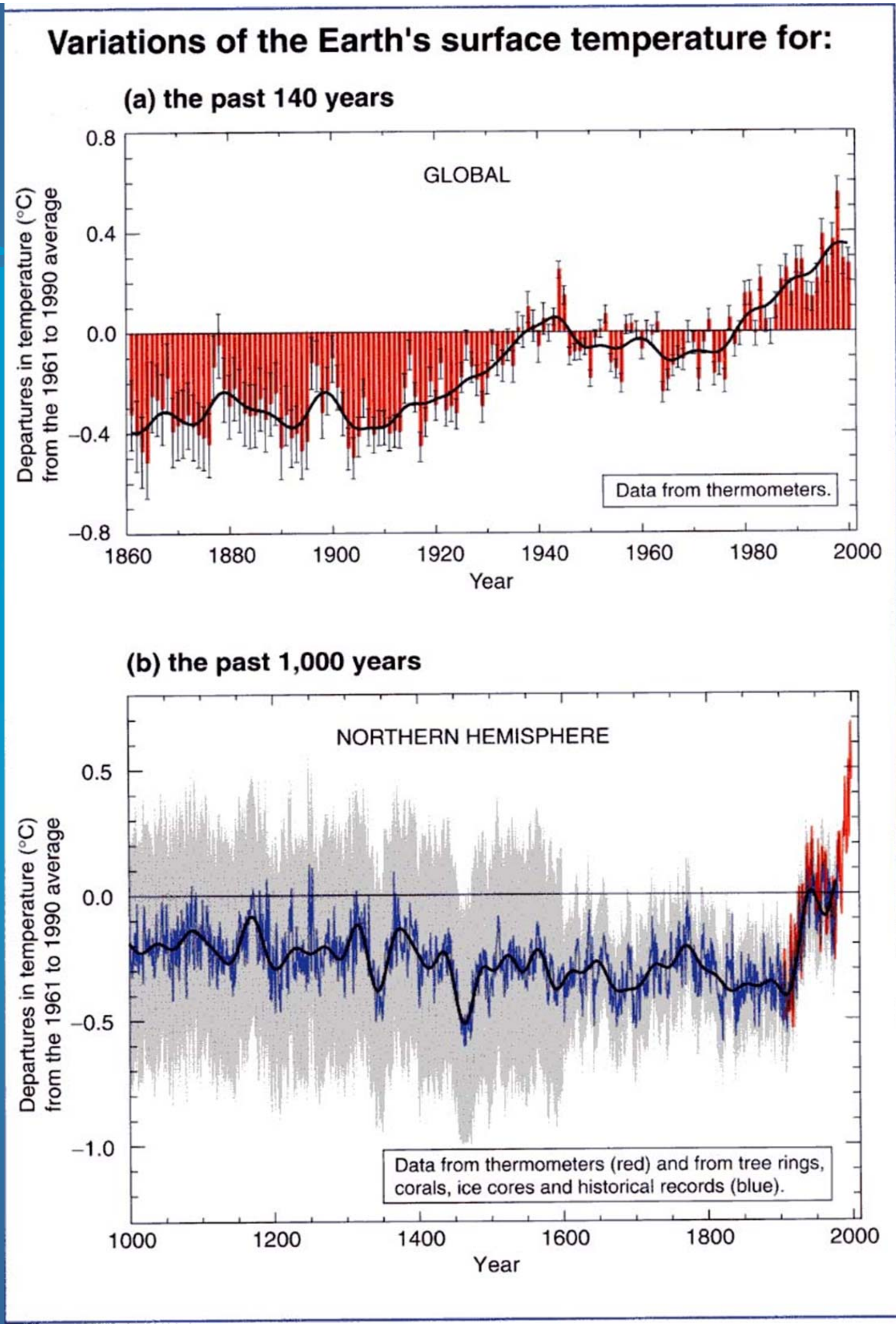
Why are they important?

What are they?

Where do they come from?

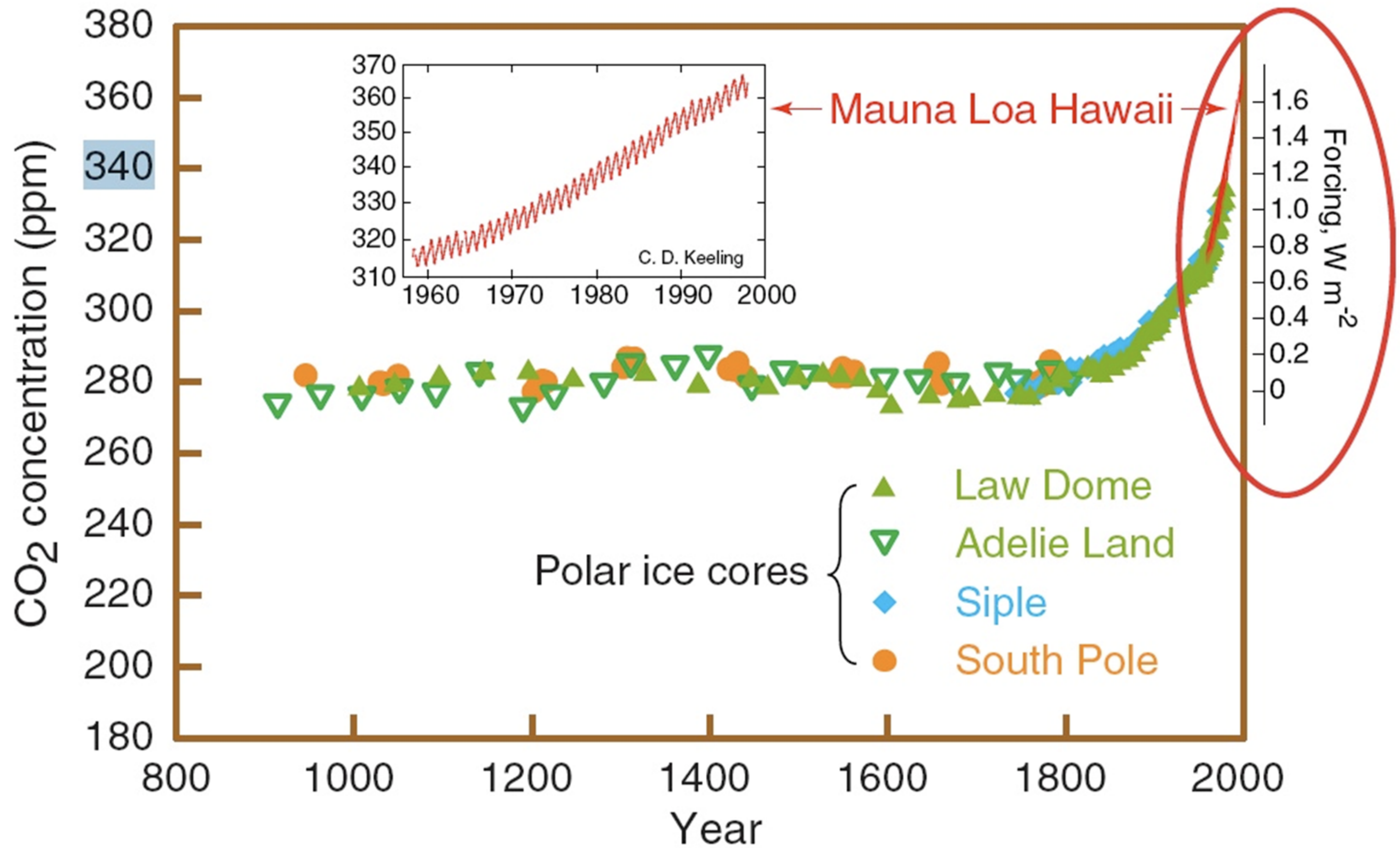
How are they measured?

What is AERONET all about?


Variations of the Earth's surface temperature for:
(a) the past 140 years
GLOBAL
Data from thermometers.
Departures in temperature (°C) from the 1961 to 1990 average
0.8
0.4
0.0
−0.4
−0.8
1860
1880
1900
1920
1940
1960
1980
2000
Year
(b) the past 1,000 years
NORTHERN HEMISPHERE
Data from thermometers (red) and from tree rings, corals, ice cores and historical records (blue).
Departures in temperature (°C) from the 1961 to 1990 average
0.5
0.0
−0.5
−1.0
1000
1200
1400
1600
1800
2000
Year

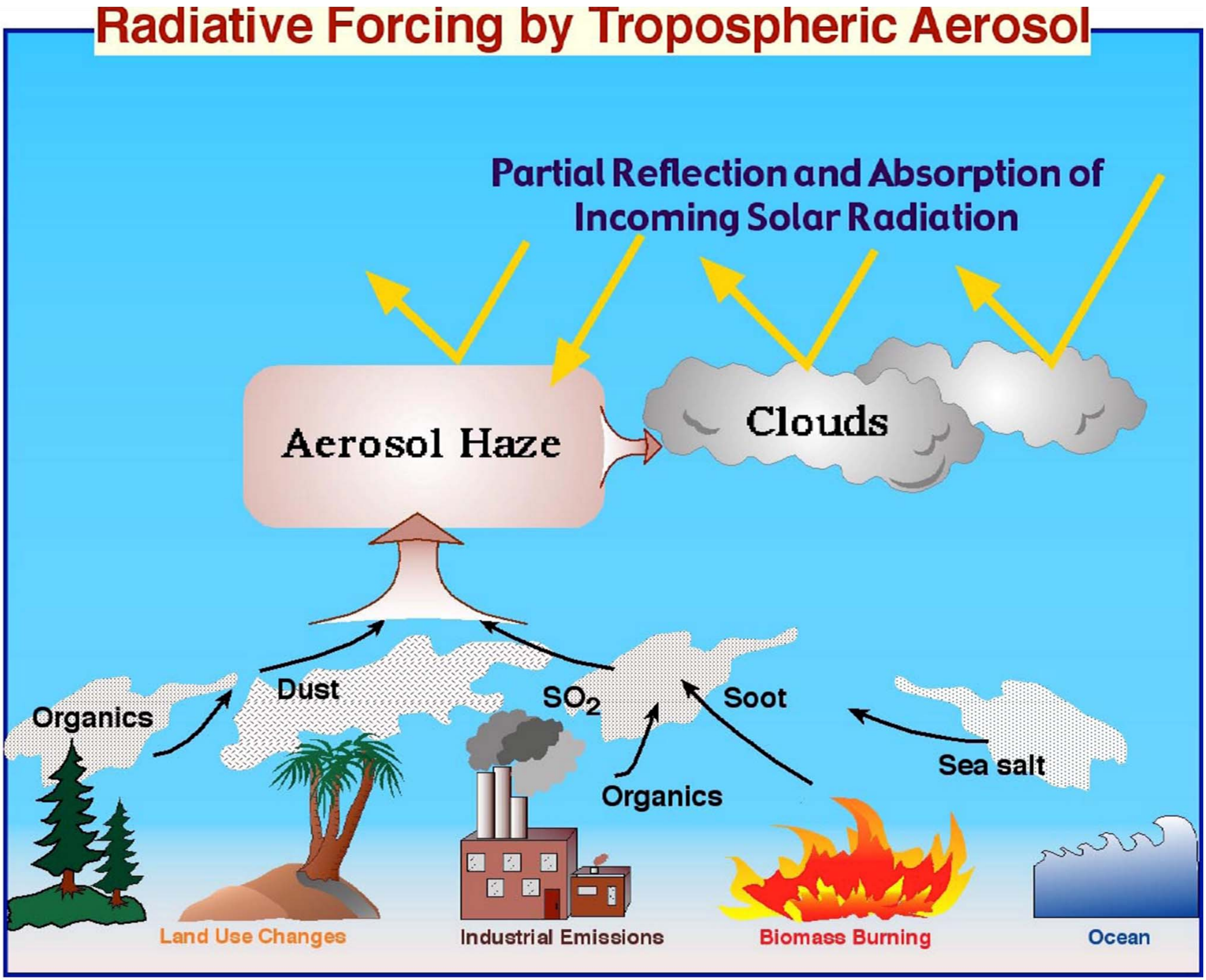
IPCC-2001

ATMOSPHERIC CARBON DIOXIDE IS INCREASING



Global carbon dioxide concentration and infrared radiative forcing over the last thousand years

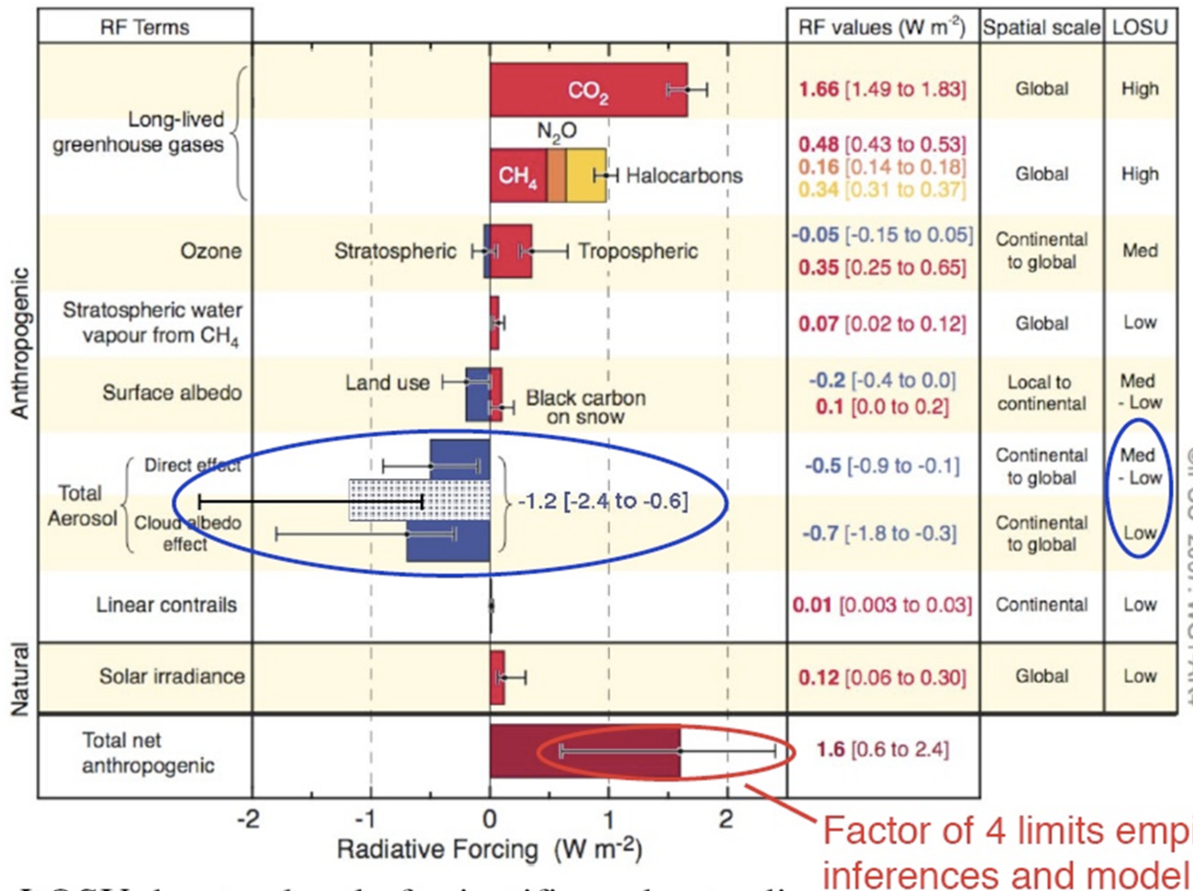
AEROSOLS
THE “MONKEY WRENCH” OF FORCING

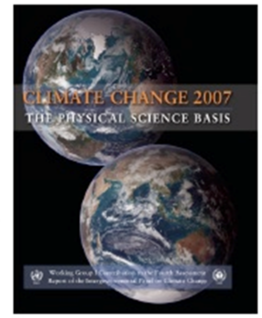


Radiative Forcing by Tropospheric Aerosol
Partial Reflection and Absorption of
Incoming Solar Radiation
Aerosol Haze
Clouds
Organics
Dust
SO_2
Soot
Organics
Sea salt
Land Use Changes
Industrial Emissions
Biomass Burning
Ocean

GLOBAL-MEAN RADIATIVE FORCINGS (RF)

Pre-industrial to present (Intergovernmental Panel on Climate Change, 2007)



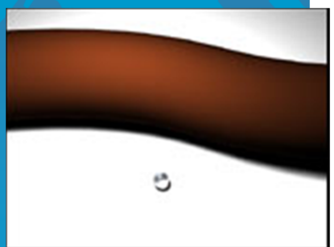


LOSU denotes level of scientific understanding.

What is an AEROSOL particle?

- Liquid or solid particle suspended in the atmosphere
- Size: Typically 0.01 to 20 μm in diameter
- Composition:
  - Liquid: Water, sulfate, sea salt
  - Solid: Carbon, mineral (dust)
- Shape: Spherical to angular
- Types: Anthropogenic, Natural <biogenic>

Sea salt and aged sea salt	Cl+Na+S>85%
Ammonium sulfates	S>85%, beam damage
Silicates	Al+Si>60%
Metal oxides/hydroxides	metals (Al, Ti, Mn, Fe, Cu, Ni, Zn or Pb)>80%
Calcium sulfates	Ca>30% and S>40%
Carbonates	Ca>60% and S<20%
Carbon-Rich Particles (C > 25%)	Criteria Based on Morphology, on Beam Resistance, and on Relative X-Ray Intensities (Sum of Net Counts of Elements With $6 \leq Z \leq 82$ = 100%)
Soot	morphology
Biological	morphology and/or characteristic minor elements (Na, Mg, P, S, Cl, K and Ca)
Carbon/sulfate mixed particles	S>15% and/or morphology, beam damage
C_{rest}	rest of carbon-rich particles



Hair: ~100 µm
Water drop: 14 µm
Sea salt: 1 µm

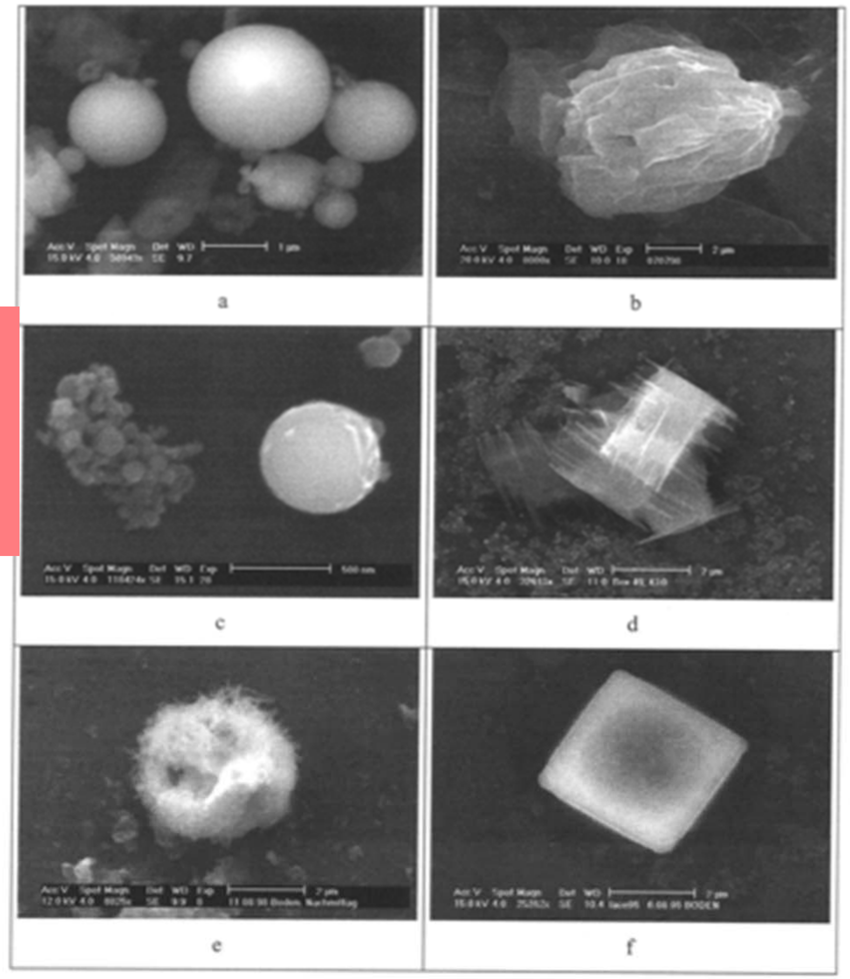
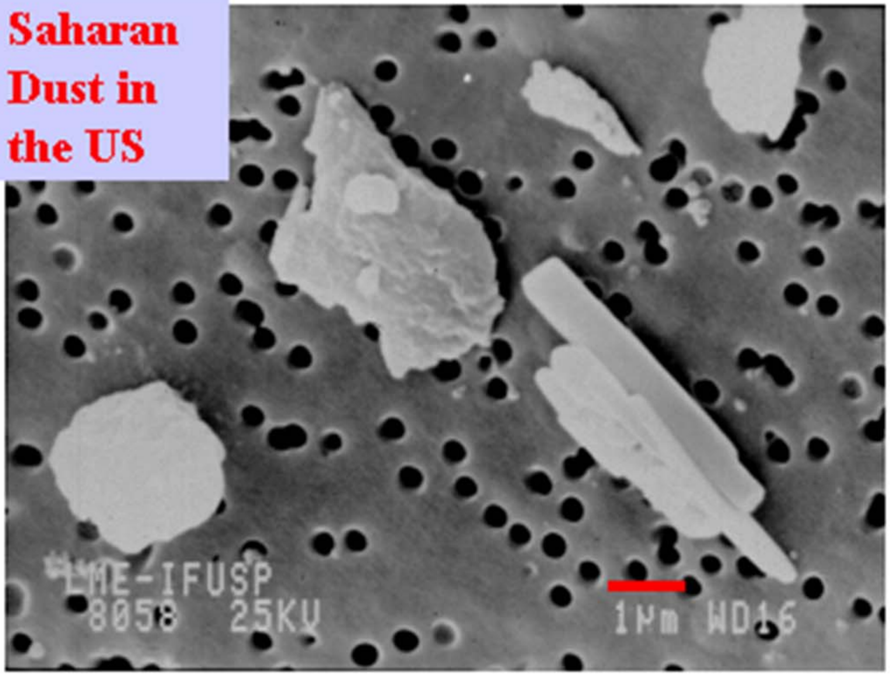


Figure 1. Secondary electron images of aerosol particles: (a) silicate spheres (fly ash); (b) silicate (presumably soil material); (c) iron oxides spheres; (d) calcium sulfate; (e) carbonate; (f) sea salt; (g) biological particle; (h) carbon/sulfate mixed particles; (i) large soot agglomerate and small silicate fly ash particles (bright spheres); (j) ammonium sulfate agglomerates; (k) soot (1), ammonium sulfate (2), and carbon/sulfate mixed particles (3); (l) carbon-rich particle (C_{rest}).

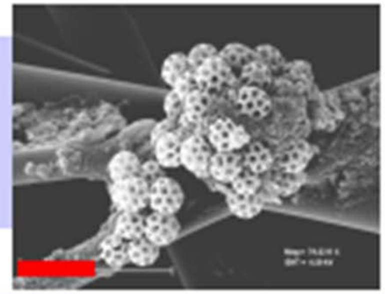
Types of Particles

University of Sao Paulo – Institute of Physics

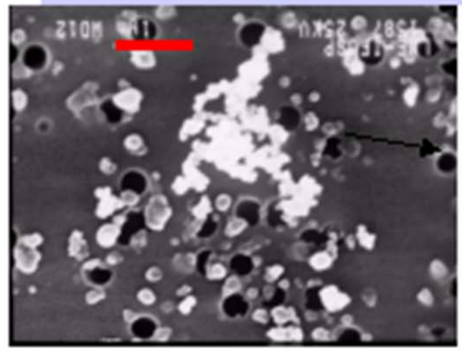
Saharan Dust in the US

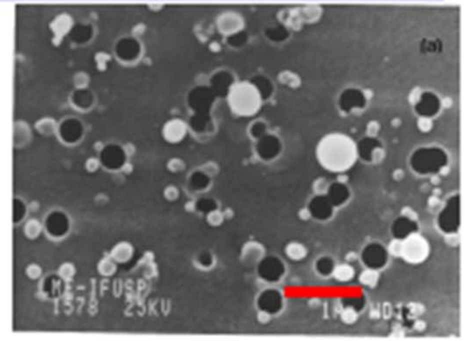


Amazon: Biogenic Cluster

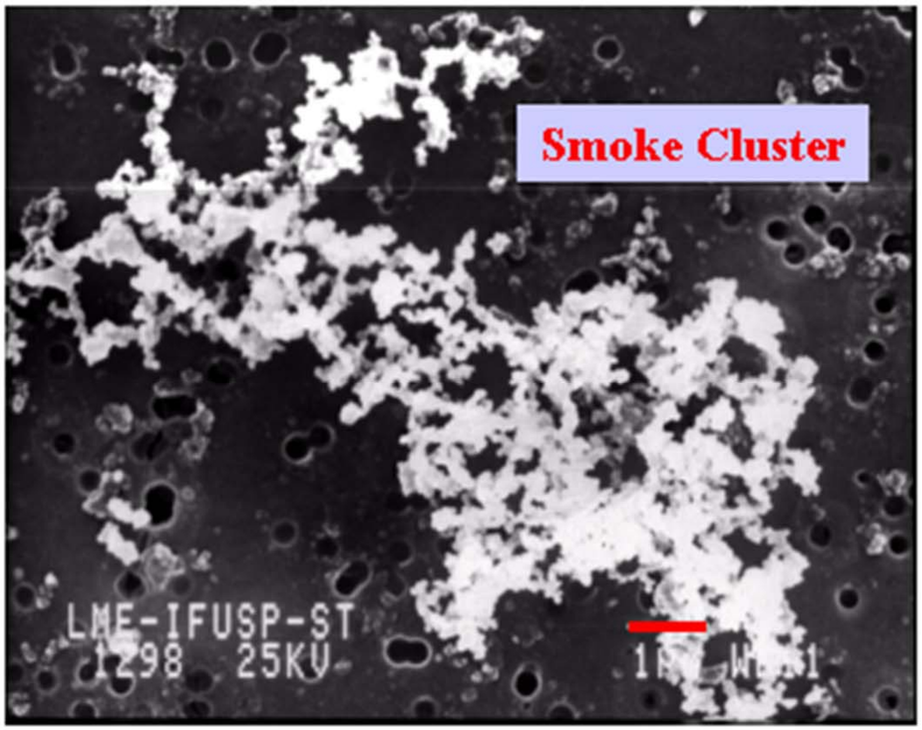


Flaming Smoke Smoldering

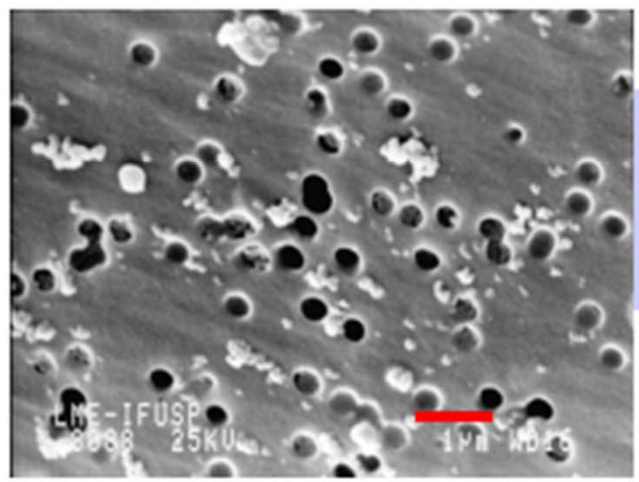




Smoke Cluster



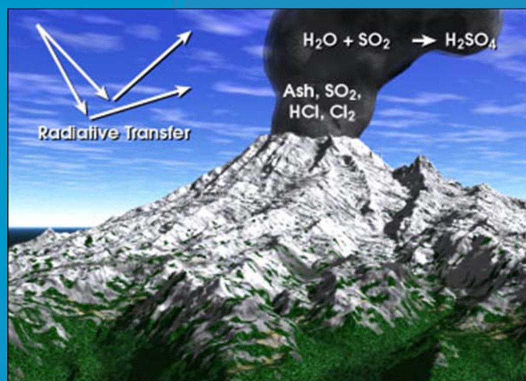
US Urban Pollution



What are the sources of aerosol particles?

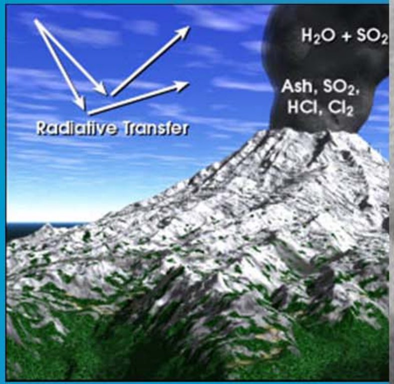
- Natural (~90%)
  - Volcanoes
  - Dust storms
  - Wildfires
  - Vegetation
  - Sea spray
- Anthropogenic (~10% but mostly in N. hemisphere)
  - Industrial emissions
  - Fossil Fuel combustion
  - Land use/land cover changes

Aerosol sources- Volcanoes



- Particles and SO_2 may reach the stratosphere, 22 km
- Photo chemical conversion to SO_4 aerosols
- Transported globally, cools the surface, direct effect

Aerosol s
Volca



- Particles and S… km
- Photo chemica…
- Transported g… ect

Natural Aerosols

Marine aerosols, wind/wave generated, large particles (>1μm), lowest 100 m, Non absorbing, restricted to oceans, conc. low

Aerosols from Biomass Burning

Flaming Phase⇒oxygen starved, black carbon, absorbing

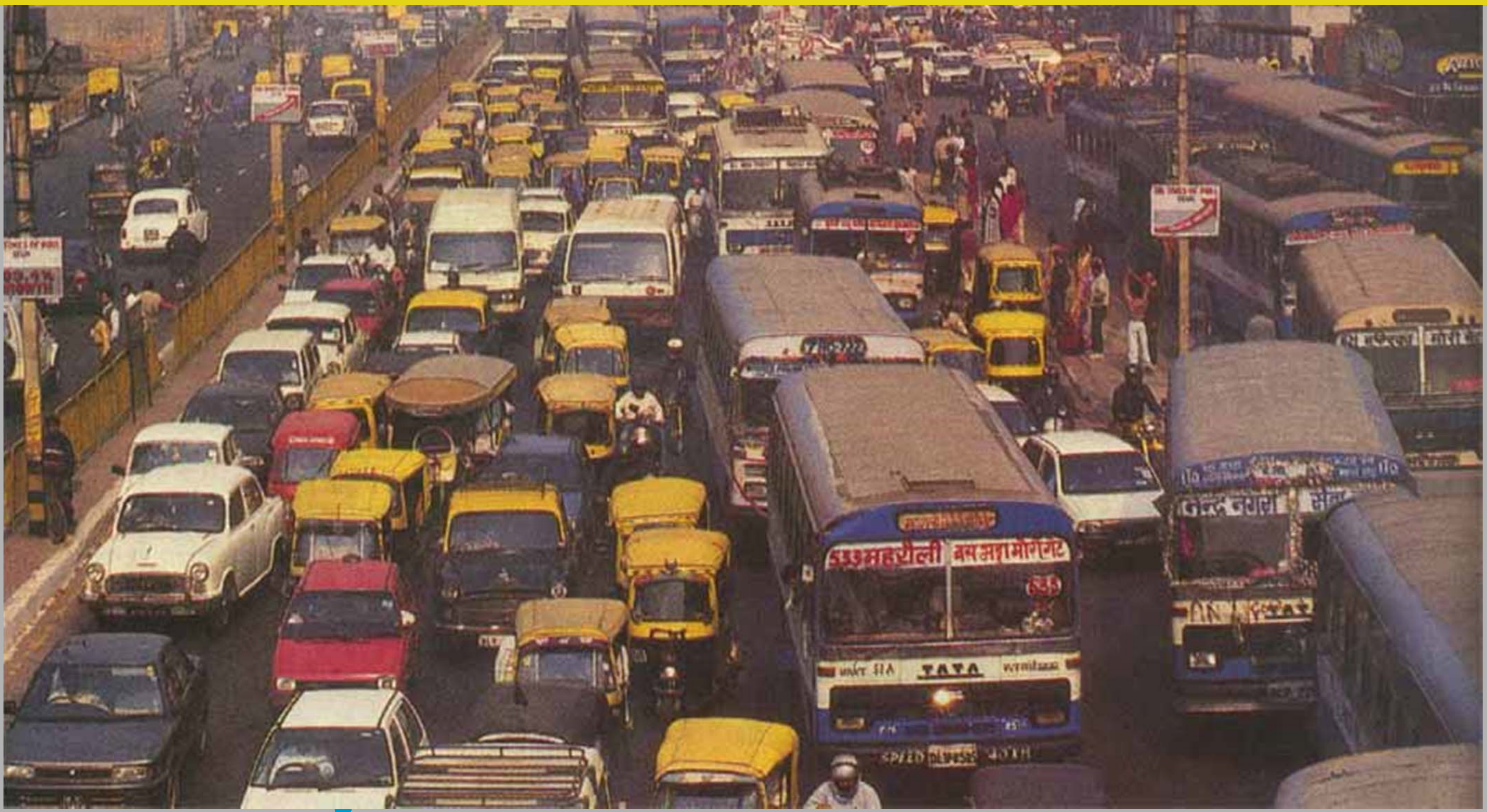
Smoldering Phase ⇒oxygen rich combustion, non absorbing

Dust-Natural and Anthropogenic sources

Anthropogenic: Urban Aerosols

Black Carbon (highly absorbing): diesel engines, coal

SO_4(small, non absorbing): factories, power plants, gas engines

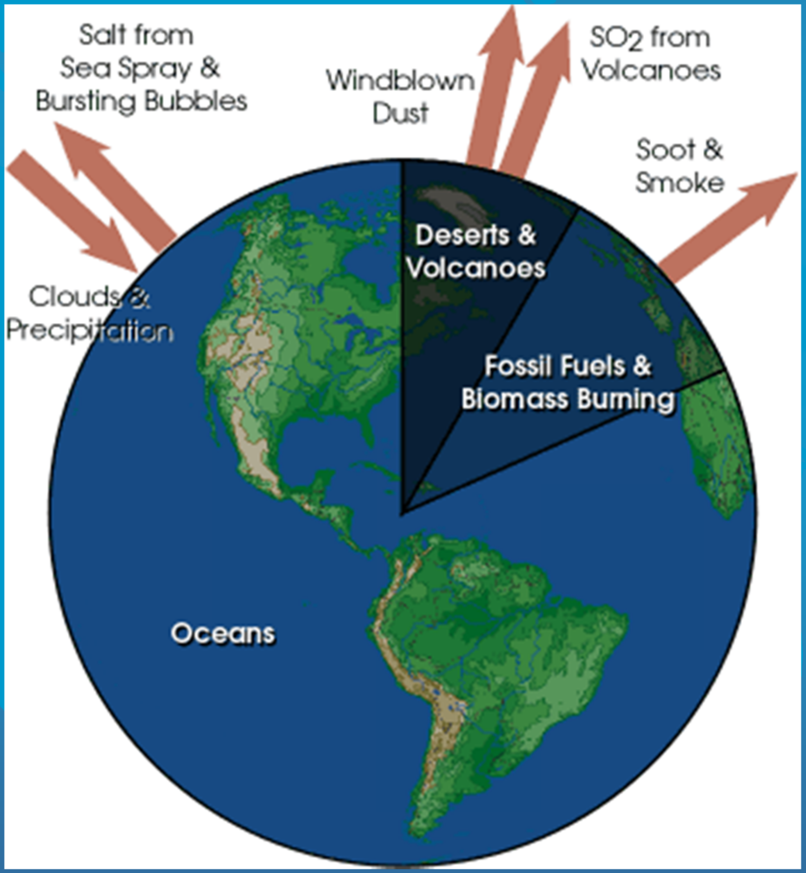


Bhaskar Paul

Source: India Today, December 15, 1996, pg. 50.

The lives of aerosols

- Dust and sea salt spray, >1 micron radius
- Sulfate, soot and smoke generated from conversion processes, <1 micron radius, potential health issues
- Mixed and transported by atmospheric winds
- Removed by precipitation and sedimentation
- Duration 5 to 14 days
- Episodic events make prediction and global impact uncertain



Why should we care about aerosols? -the 'Direct effect'

Mediterranean coast of Turkey

- Climate Change
  - In the absence of clds they have a direct cooling effect reflecting sunlight back to space
  - Magnitude depends on size, concentration, composition and surface reflectance
  - Aerosol cooling may partially offset global CO_2 warming
- Health effects

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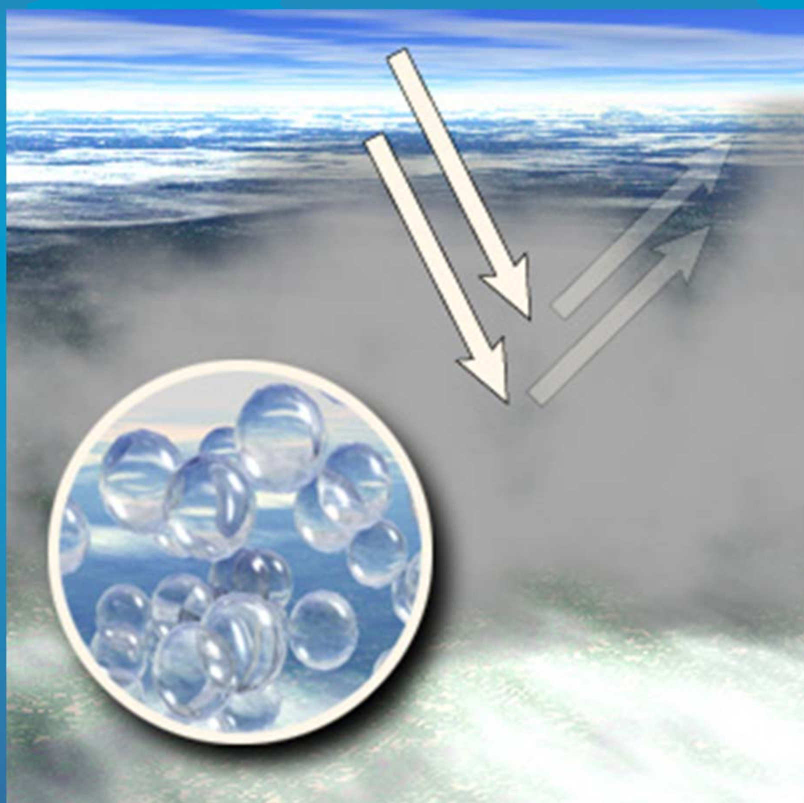
Another reason we should care-the 'Indirect' effect: Modifies Clouds and Precipitation



- Without aerosols there would be few clouds
- Few aerosols, dark clds & rain
- More aerosols result in more and smaller cloud drops-<u>less rain</u>
- More cloud drops, brighter clouds, <u>more sun light reflected to space</u>

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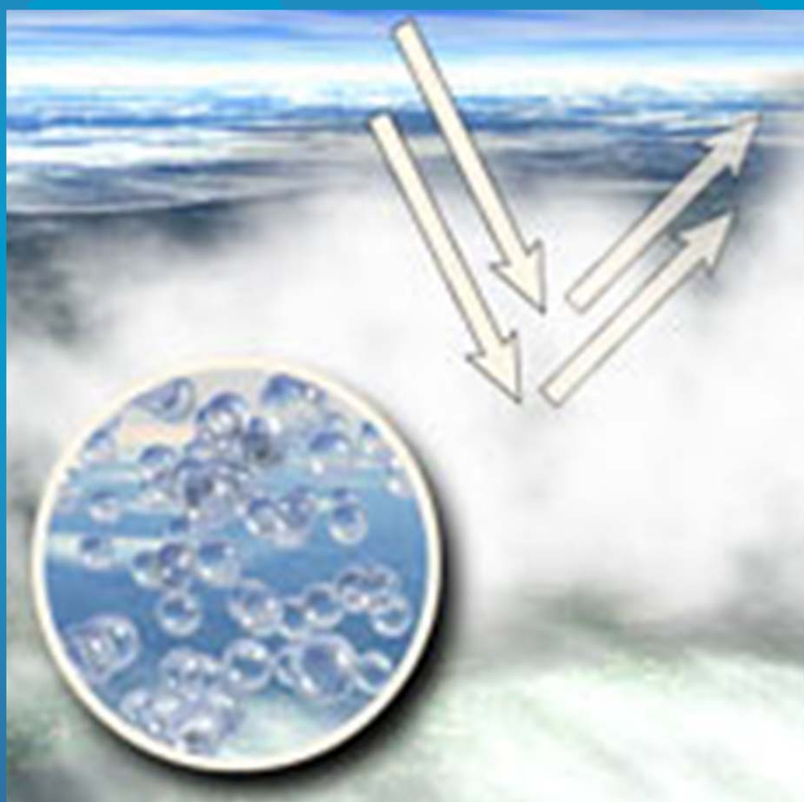

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- More cloud drops, brighter clouds, <u>more sun light reflected to space</u>

What we <u>don't</u> know about aerosols?

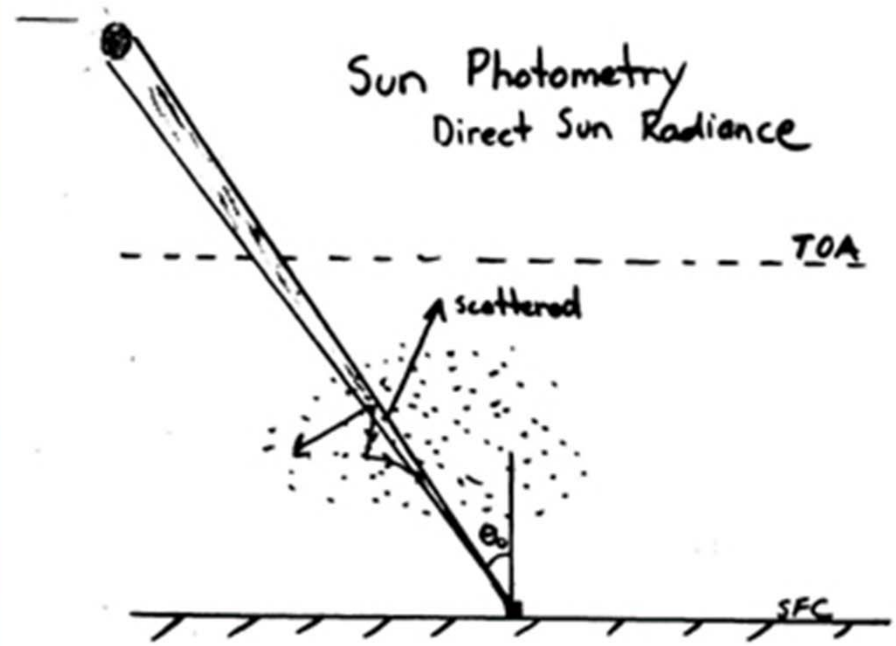
- We don't know to what extent aerosols affect regional and global climate
- We don't know the relative magnitude of natural vs man-made aerosols on climate
- We don't know where on the planet aerosols are increasing, decreasing or are unchanged
- We don't know with certainty, if aerosols are heating or cooling the planet
- We don't know the aerosol burden over the planet at any point in time.

Sun Photometry with GLOBE and AERONET

- A direct measurement
- Relatively simple measurement
- Highly accurate

Sun Photometry

Direct Sun Radiance



$$T = \exp\left(-\frac{\beta l}{\cos\theta_0}\right)$$

$$\frac{V}{V_0} = \exp(-\tau M)$$

V = voltage measured

V_0 = voltage at TOA

l = thickness of medium

β = optical index of the material

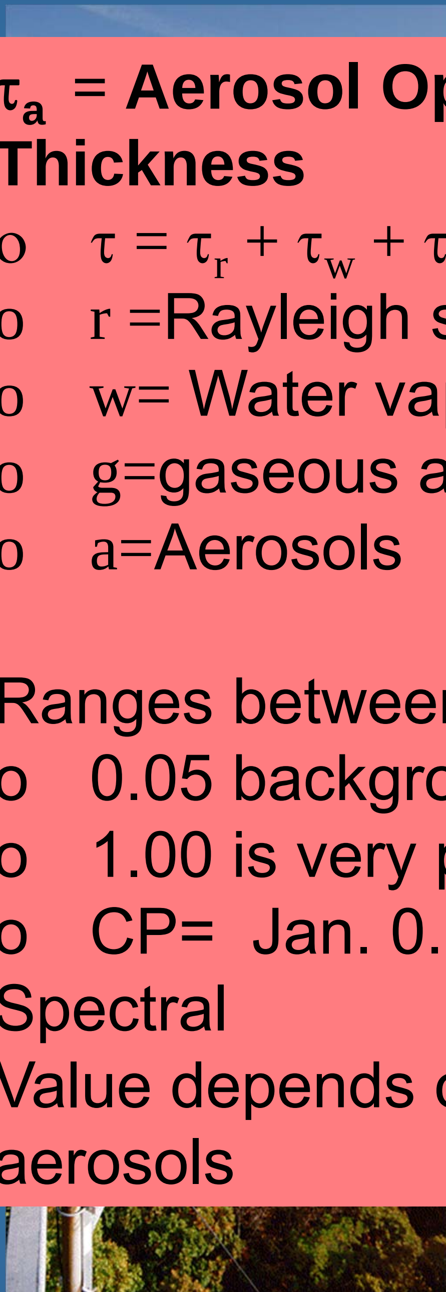
θ_0 = solar zenith angle

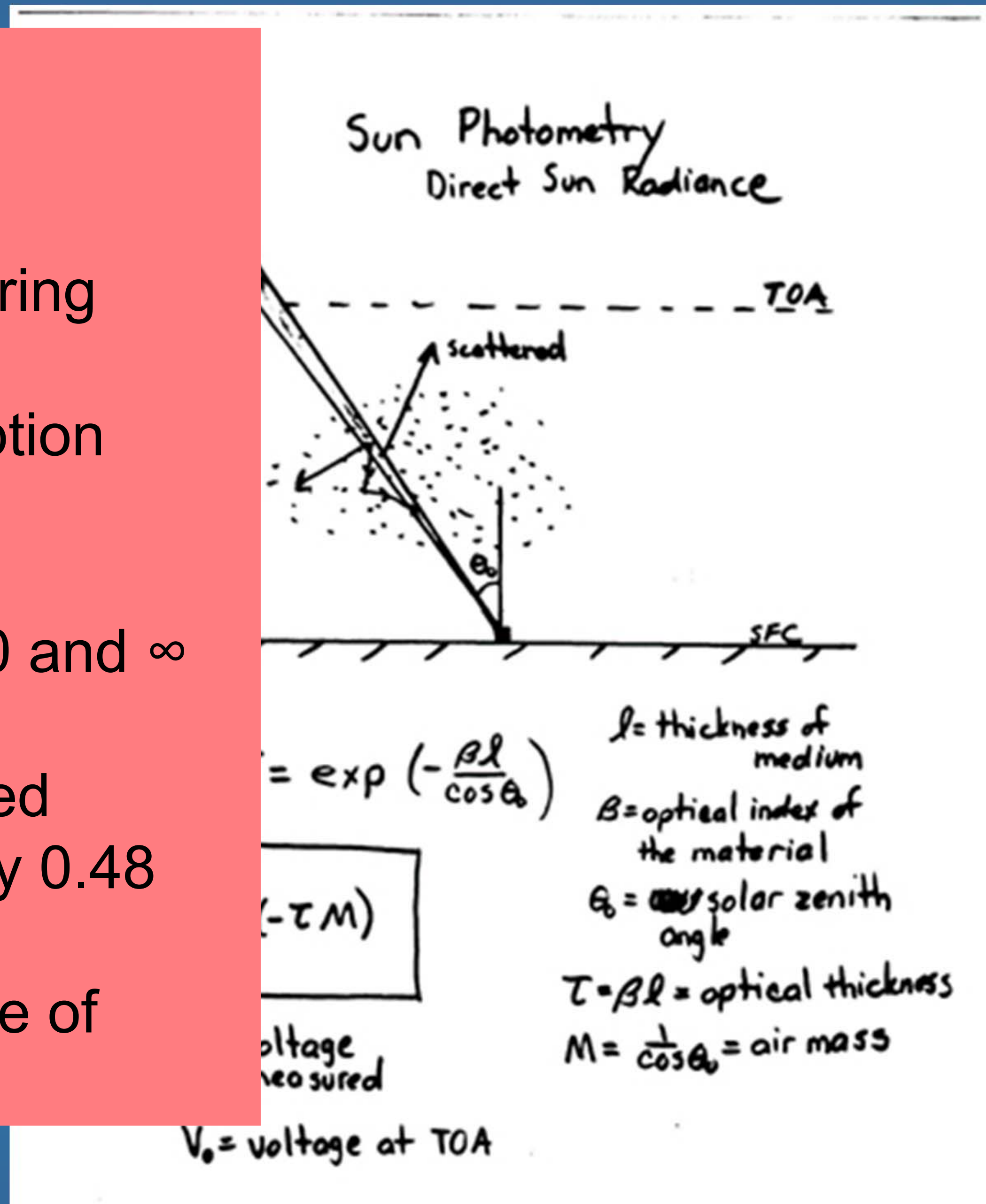
$\tau = \beta l$ = optical thickness

$M = \frac{1}{\cos\theta_0}$ = air mass

- τ_a = **Aerosol Optical Thickness**
  - o $\tau = \tau_r + \tau_w + \tau_g + \tau_a$
  - o r =Rayleigh scattering
  - o w= Water vapor
  - o g=gaseous absorption
  - o a=Aerosols

- Ranges between 0.00 and ∞
  - o 0.05 background
  - o 1.00 is very polluted
  - o CP= Jan. 0.1, July 0.48
- Spectral
- Value depends on size of aerosols





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- Spectral
- Value depends on size of aerosols

Single Scattering Albedo

$\tau_e = \tau_\alpha + \tau_s$

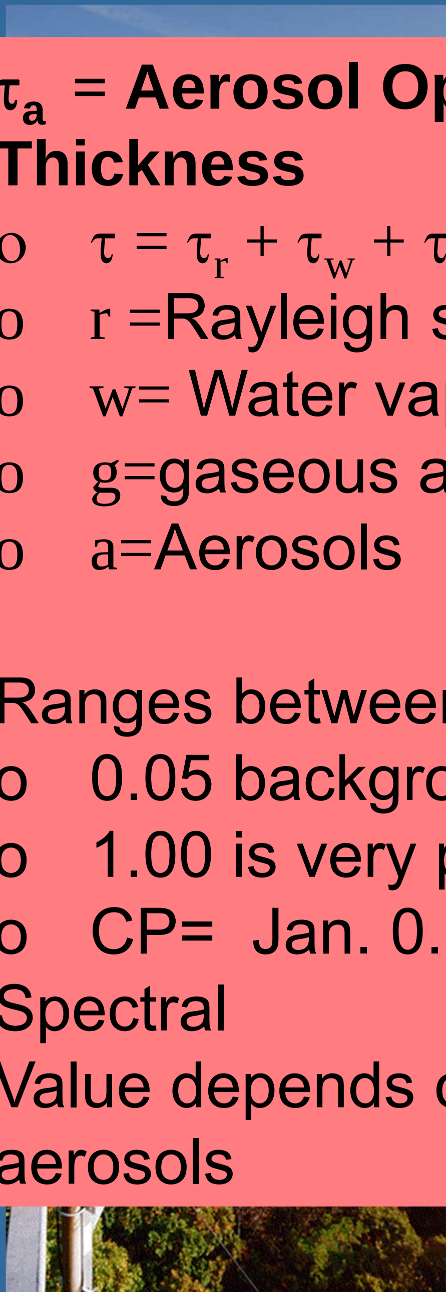
$\omega_o = \tau_s / (\tau_\alpha + \tau_s)$

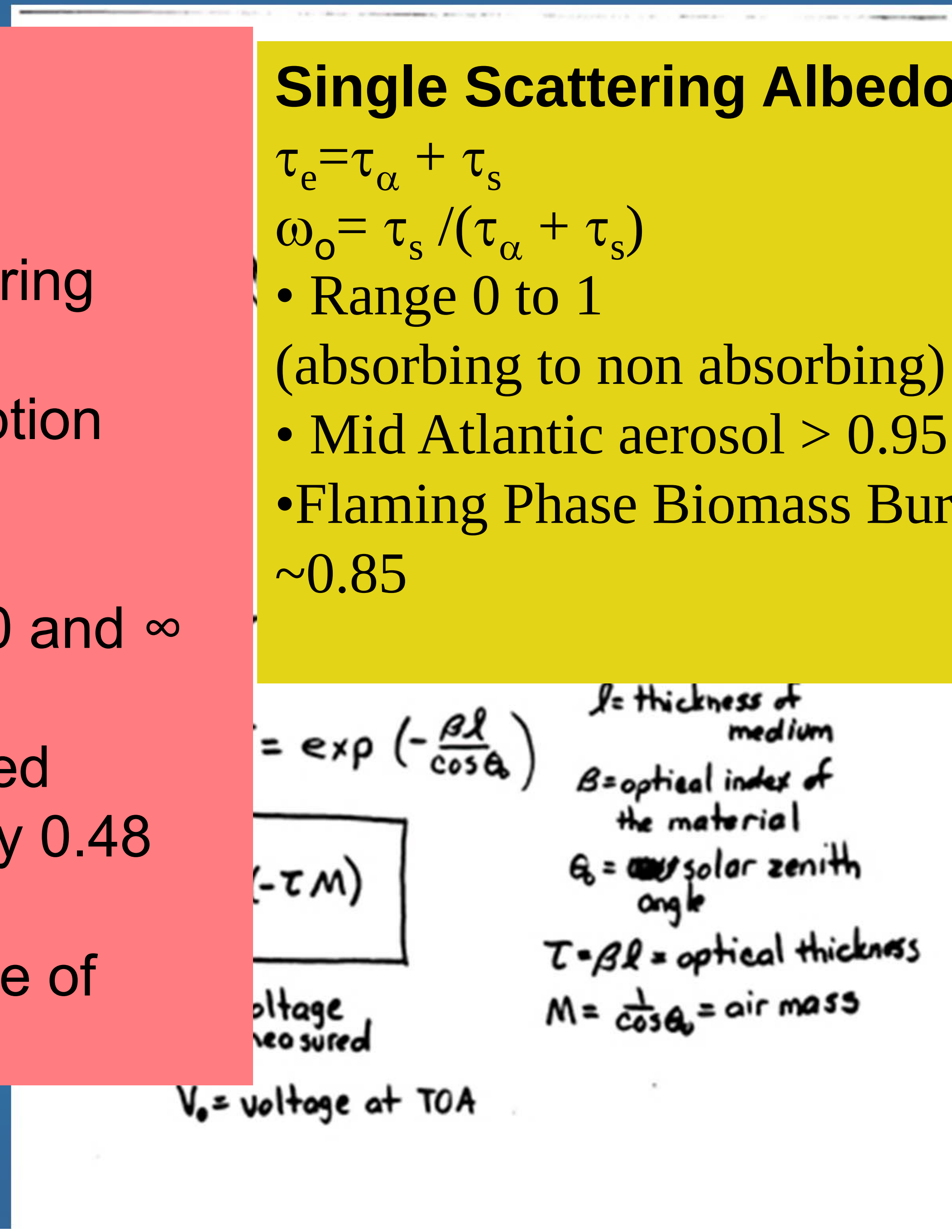
• Range 0 to 1

(absorbing to non absorbing)

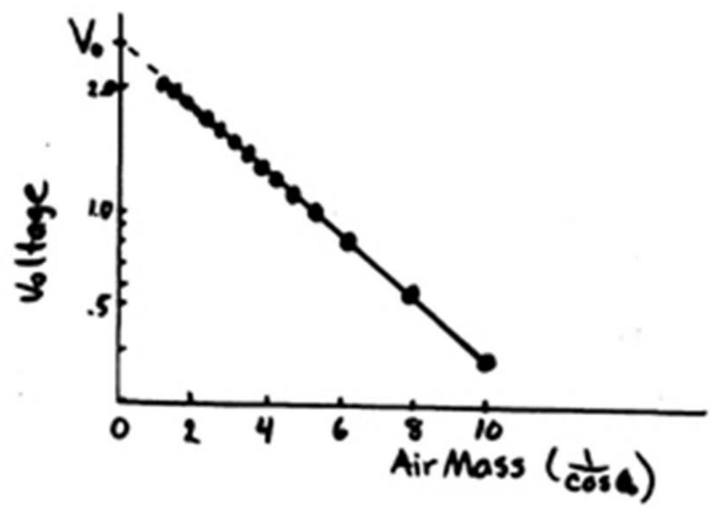
• Mid Atlantic aerosol > 0.95

•Flaming Phase Biomass Burning, ~0.85

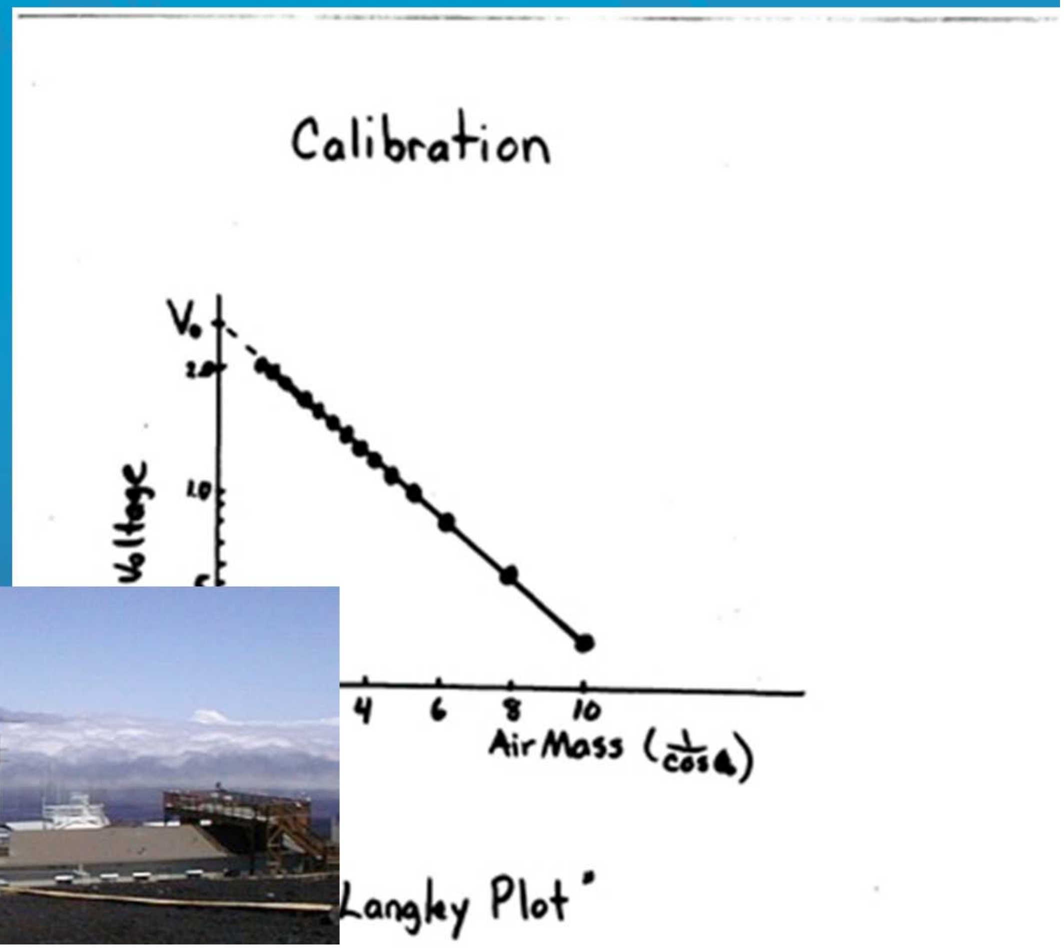




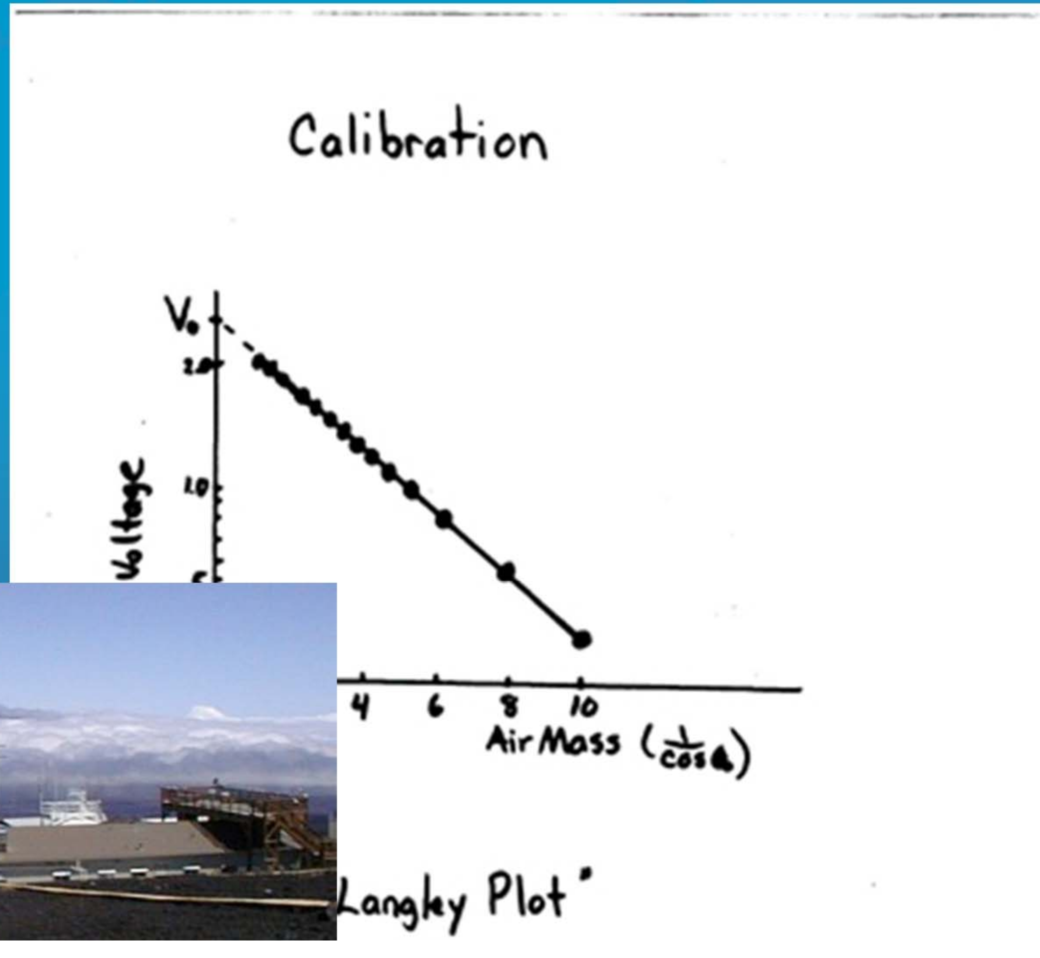
Calibration

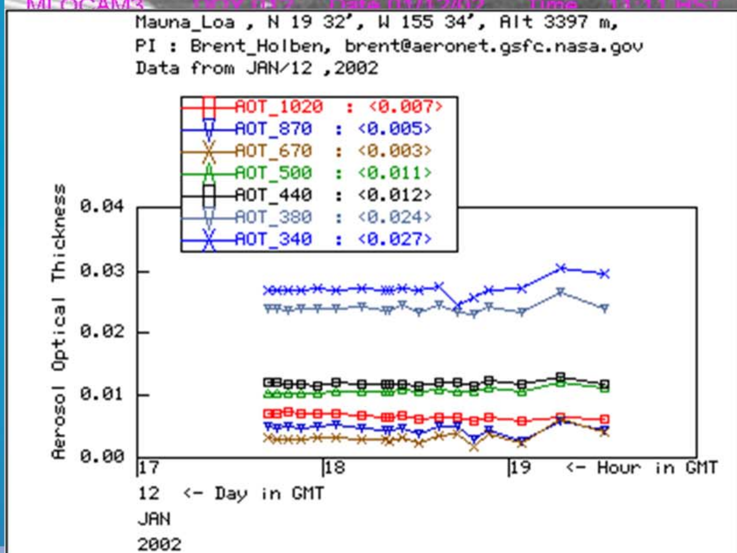


"Langley Plot"

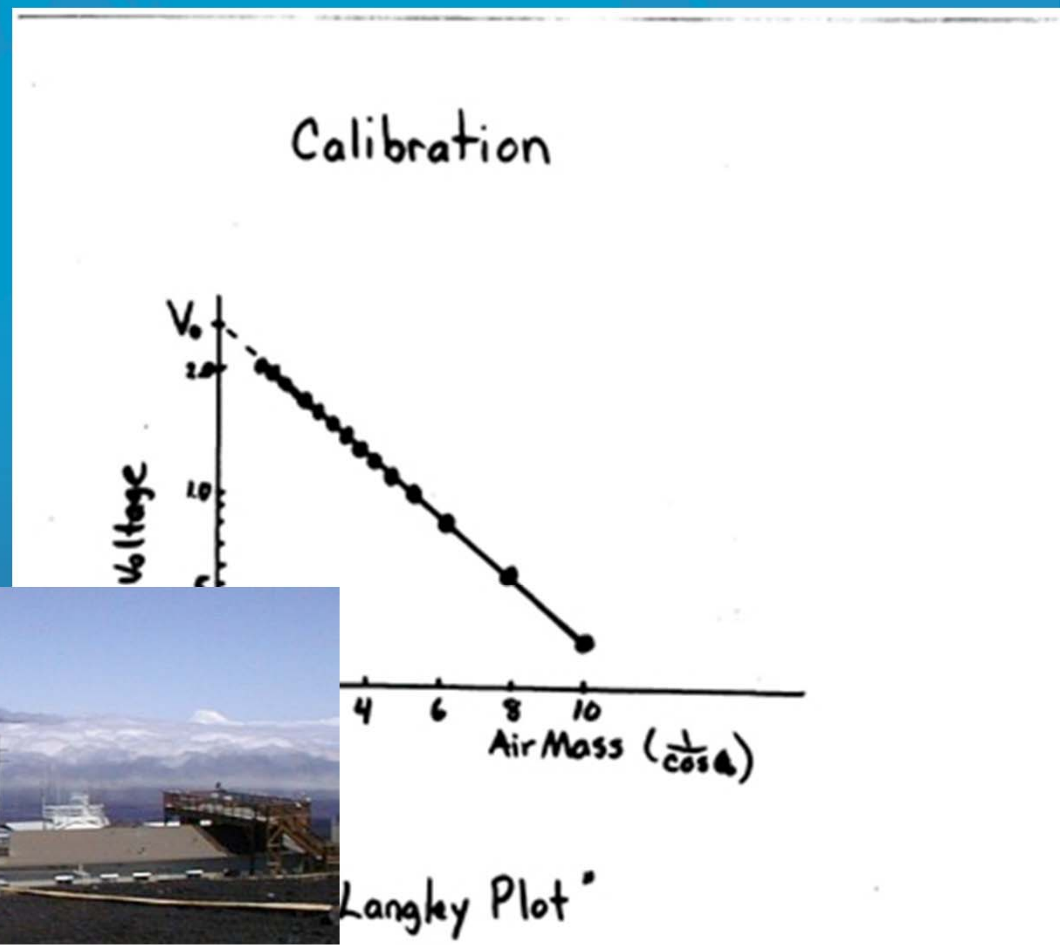

Calibration
V0
2.0
1.0
Voltage
4
6
8
10
Air Mass (1/cos θ)
Langley Plot"


MLOCAM3
DOY 012
Date 01/12/02
Time
11:11 HST

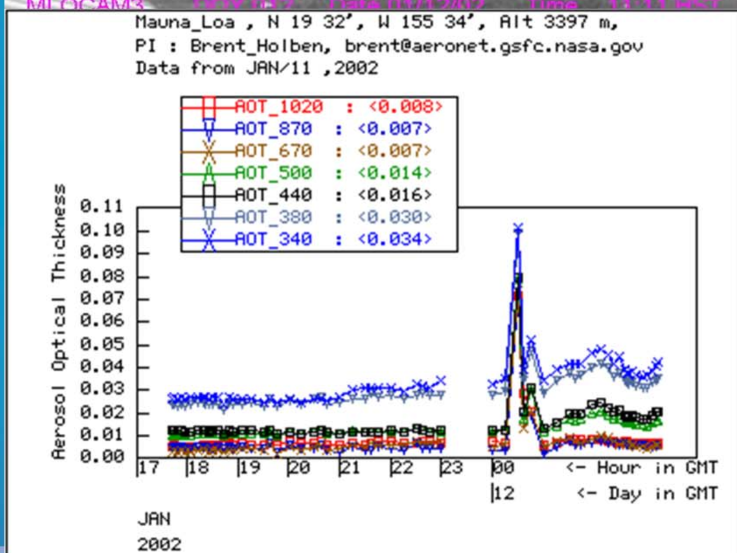

Calibration
V₀
2.0
1.0
Voltage
4
6
8
10
Air Mass (1/cosθ)
Langley Plot"



Mauna_Loa , N 19 32', W 155 34', Alt 3397 m,
PI : Brent_Holben, brent@aeronet.gsfc.nasa.gov
Data from JAN/12 ,2002
AOT_1020 : <0.007>
AOT_870 : <0.005>
AOT_670 : <0.003>
AOT_500 : <0.011>
AOT_440 : <0.012>
AOT_380 : <0.024>
AOT_340 : <0.027>
Aerosol Optical Thickness
0.04
0.03
0.02
0.01
0.00
17
18
19
<- Hour in GMT
12 <- Day in GMT
JAN
2002



Calibration
V₀
2.0
1.0
Voltage
4
6
8
10
Air Mass (1/cos θ)
Langley Plot"



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Data from JAN/11 ,2002
AOT_1020 : <0.008>
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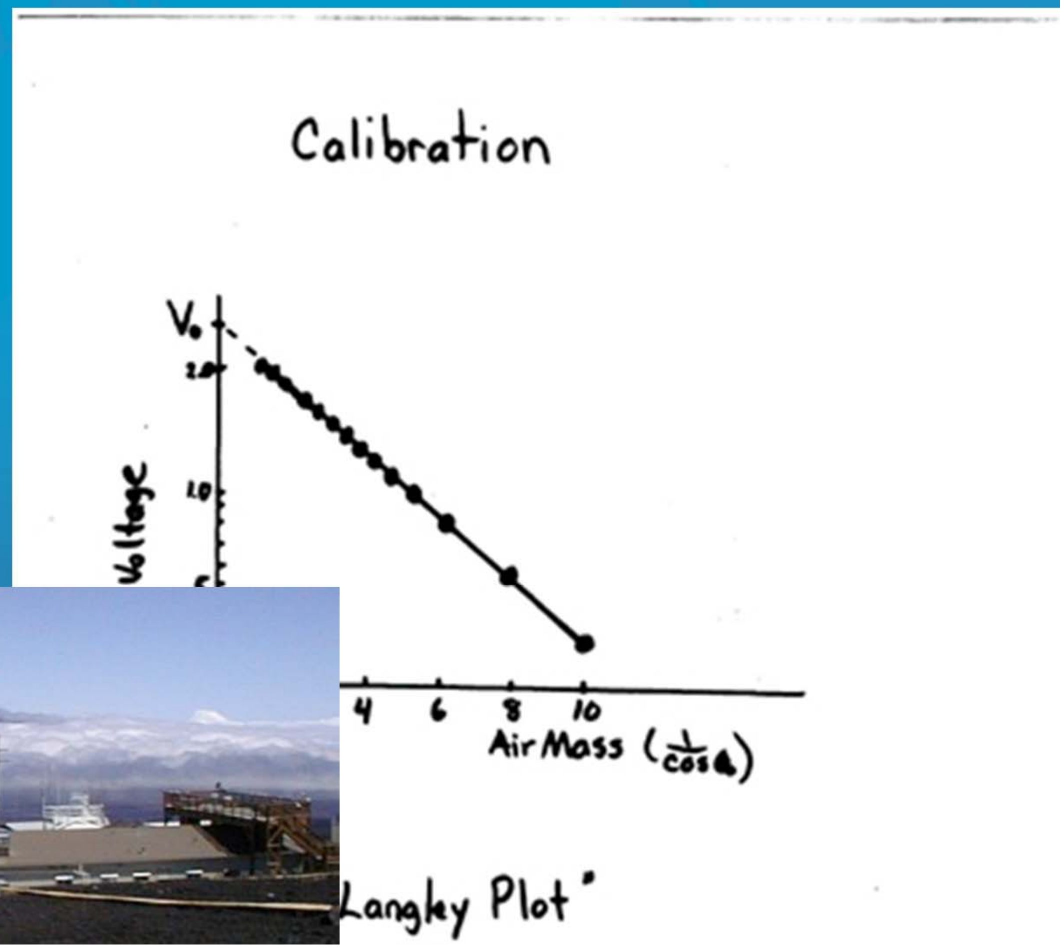
AOT_670 : <0.007>
AOT_500 : <0.014>
AOT_440 : <0.016>
AOT_380 : <0.030>
AOT_340 : <0.034>
Aerosol Optical Thickness
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
17 18 19 20 21 22 23 00
<- Hour in GMT
12
<- Day in GMT
JAN
2002



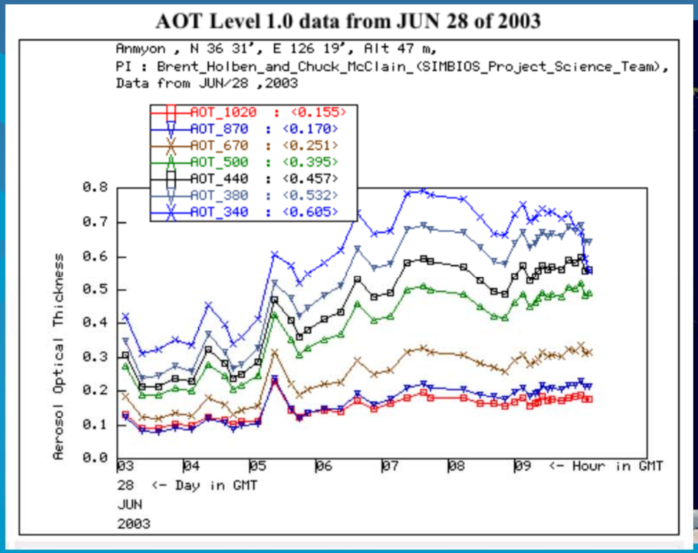
Calibration
V₀
2.0
1.0
Voltage
4 6 8 10
Air Mass (1/cos θ)
Langley Plot"

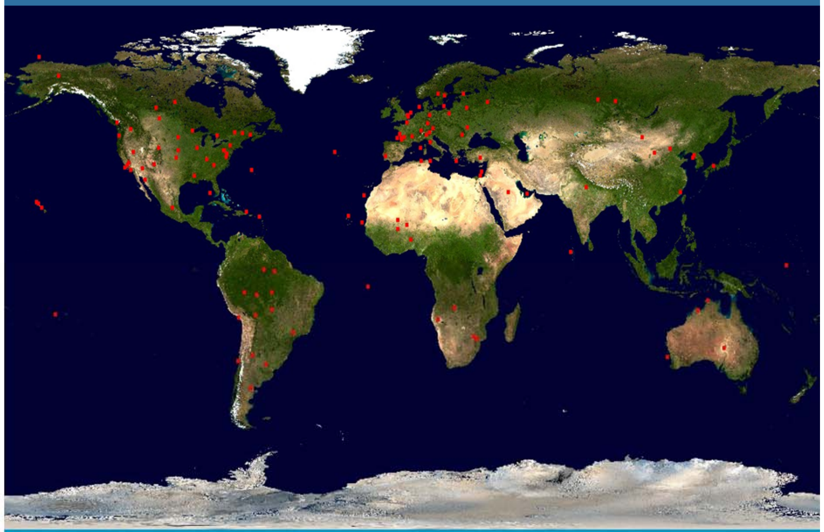
AERONET GSFC Calibration Facility

AERONET GSFC Calibration Facility

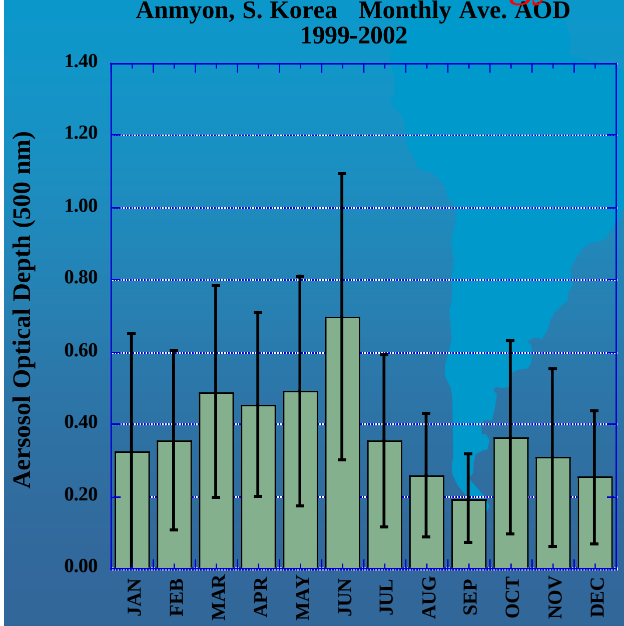
What Does AERONET Provide?

AOD 15 minute observations

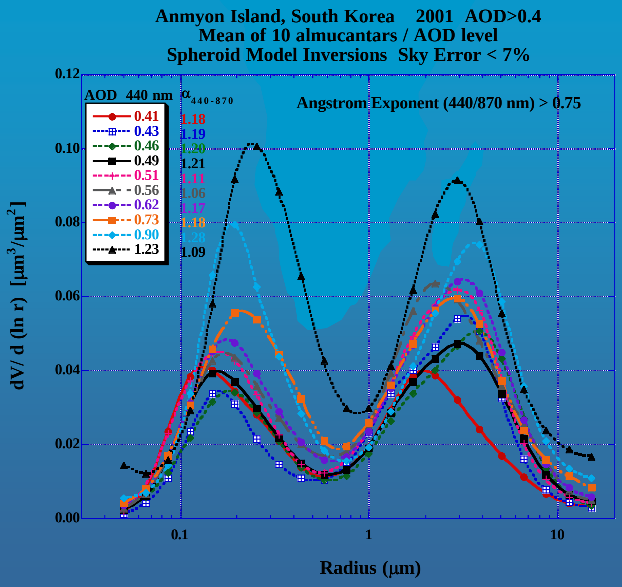




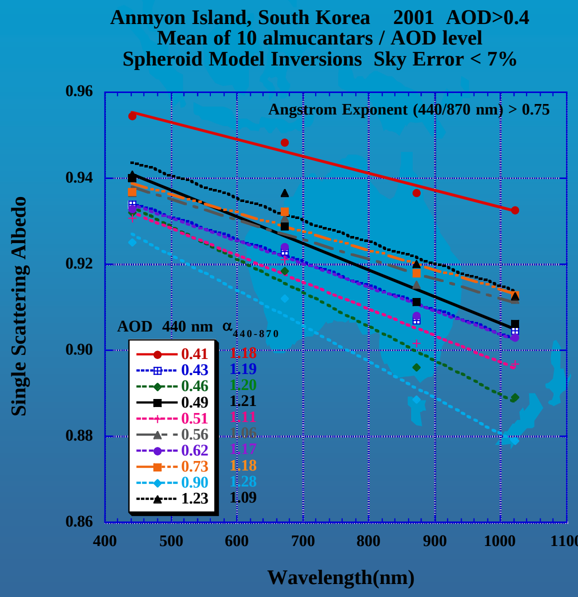
AOD Climatology



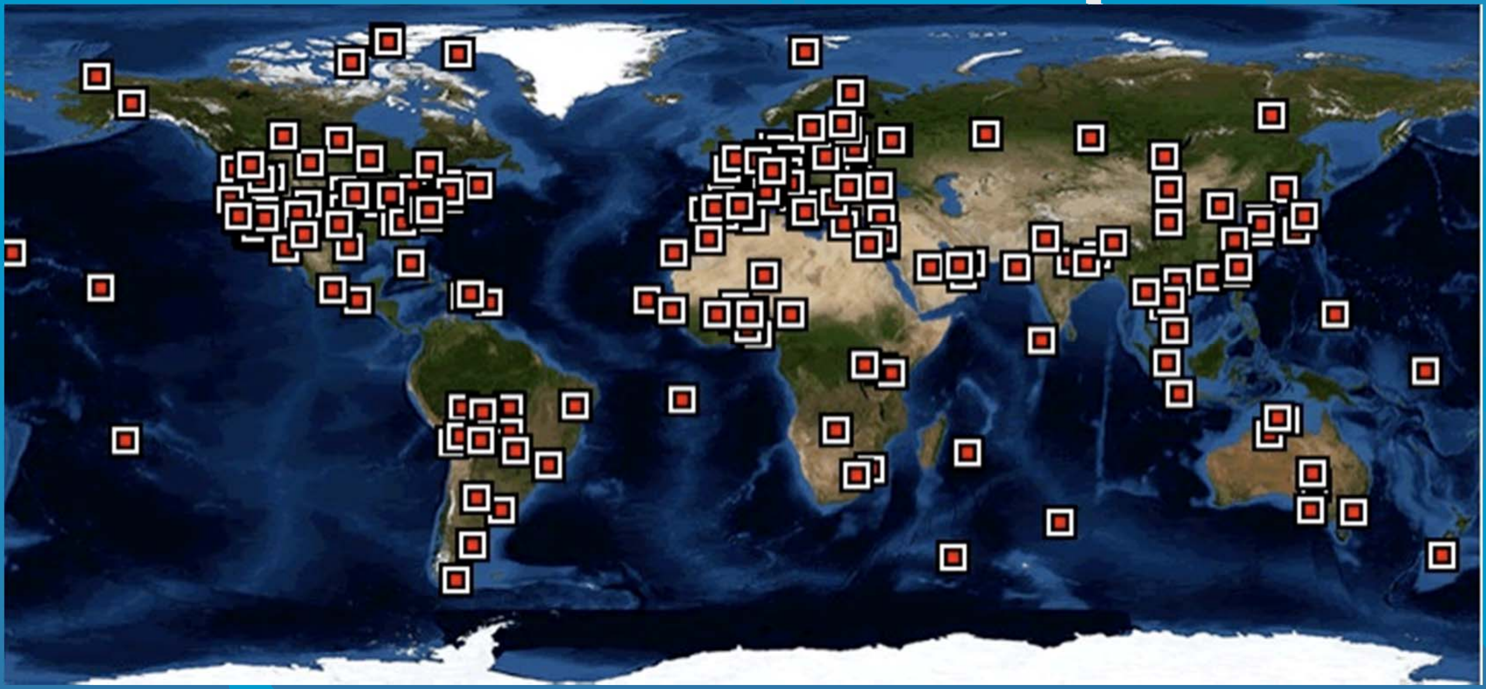
Size Distributions



Single Scattering Albedo



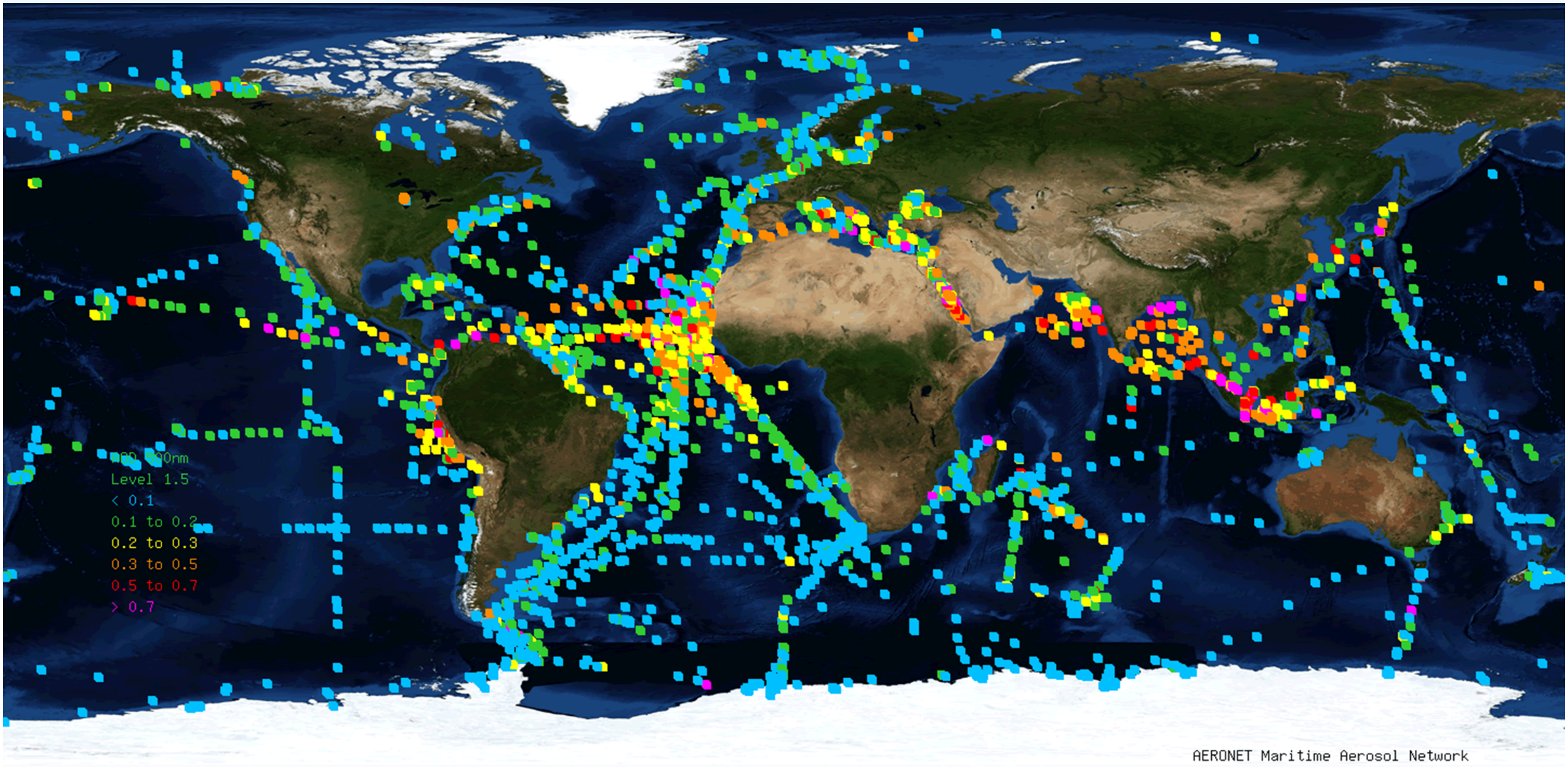
2013- 400 active sites world wide but there is still a lot of territory to cover GLOBE can Help!



Maritime Aerosol Network as a Component of AERONET

MAN represents an important strategic sampling initiative and ship-borne data acquisition complements island-based AERONET measurements

Maritime Aerosol Network global coverage from October 2006 to May 2013



Smirnov, A., et al., Maritime Aerosol Network as a component of Aerosol Robotic Network, J. Geophys. Res., 114, D06204, doi:10.1029/2008JD011257, 2009.

So what's the fuss summary

- What are aerosols?
  - Properties, composition, definition, shape, size
  - Natural vs Anthropogenic
- What are the source regions of aerosols?
  - Relate geography and aerosol type
  - People vs emissions
- Why are aerosols important?
  - Climate forcing
  - Health
  - Aesthetics

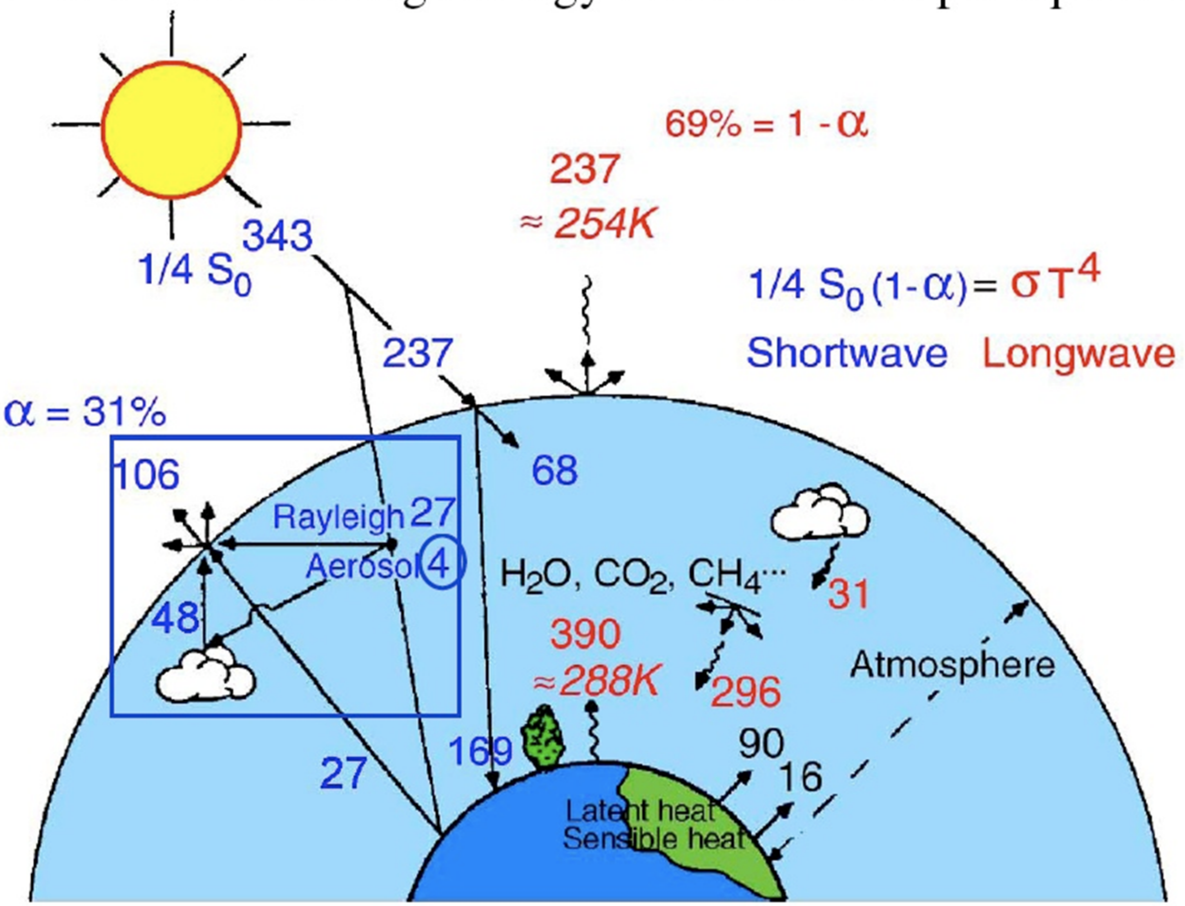
Summary cont.

- How are aerosols measured?
  - Active and passive systems
  - Satellite, airborne and ground-based
  - Sun Photometry-Globe

Extra slides

GLOBAL ENERGY BALANCE

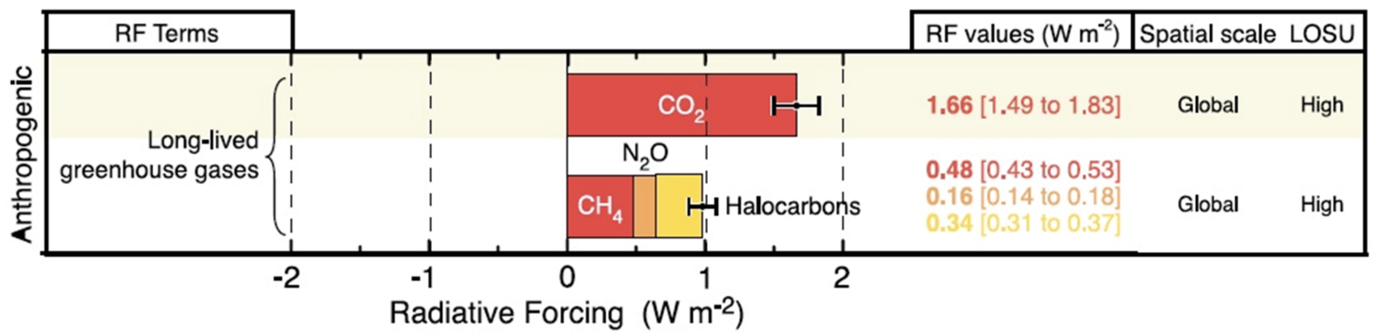
Global and annual average energy fluxes in watts per square meter



Schwartz, 1996, modified from Ramanathan, 1987

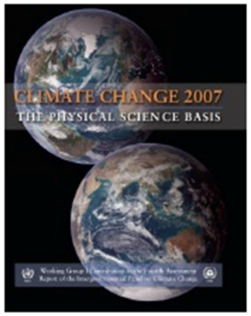
GLOBAL-MEAN RADIATIVE FORCINGS (RF) BY LONG-LIVED GREENHOUSE GASES

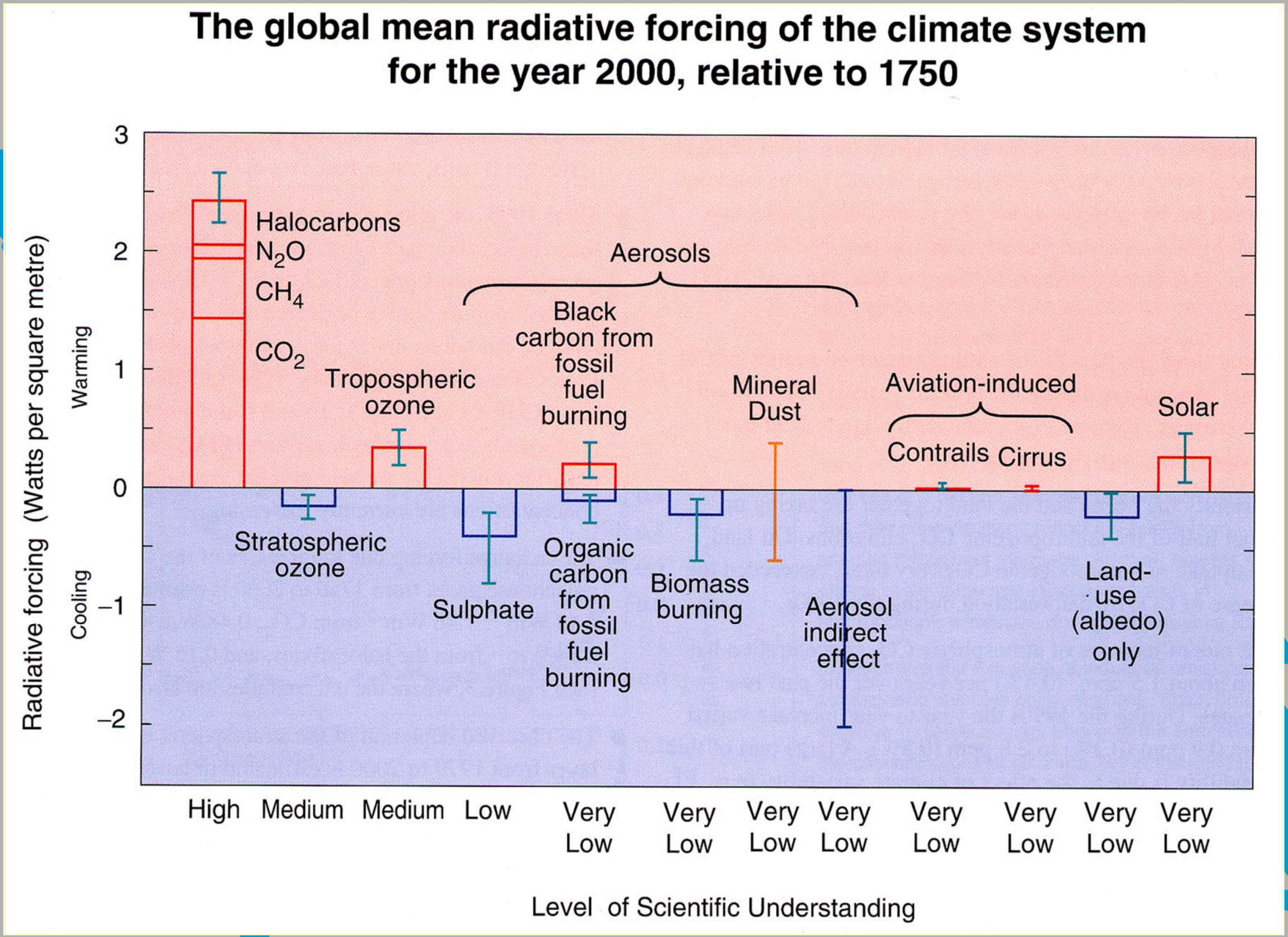
Pre-industrial to present (Intergovernmental Panel on Climate Change, 2007)



LOSU denotes level of scientific understanding.

Total radiative forcing: 2.64 ± 0.26 W m^{-2}





Source: Summary for Policymakers, *IPCC*, 2001

Aerosols-general characteristics

- Ubiquitous:
  - 5 to 1000 mg/m^3
- Remote sensing characteristics
  - Color: f(size and composition)
  - Directional Scattering efficiency: f(size)
  - Absorption: f(composition)
- Lifetime: 5 to 14 days (tropospheric)

  years (stratsopheric)