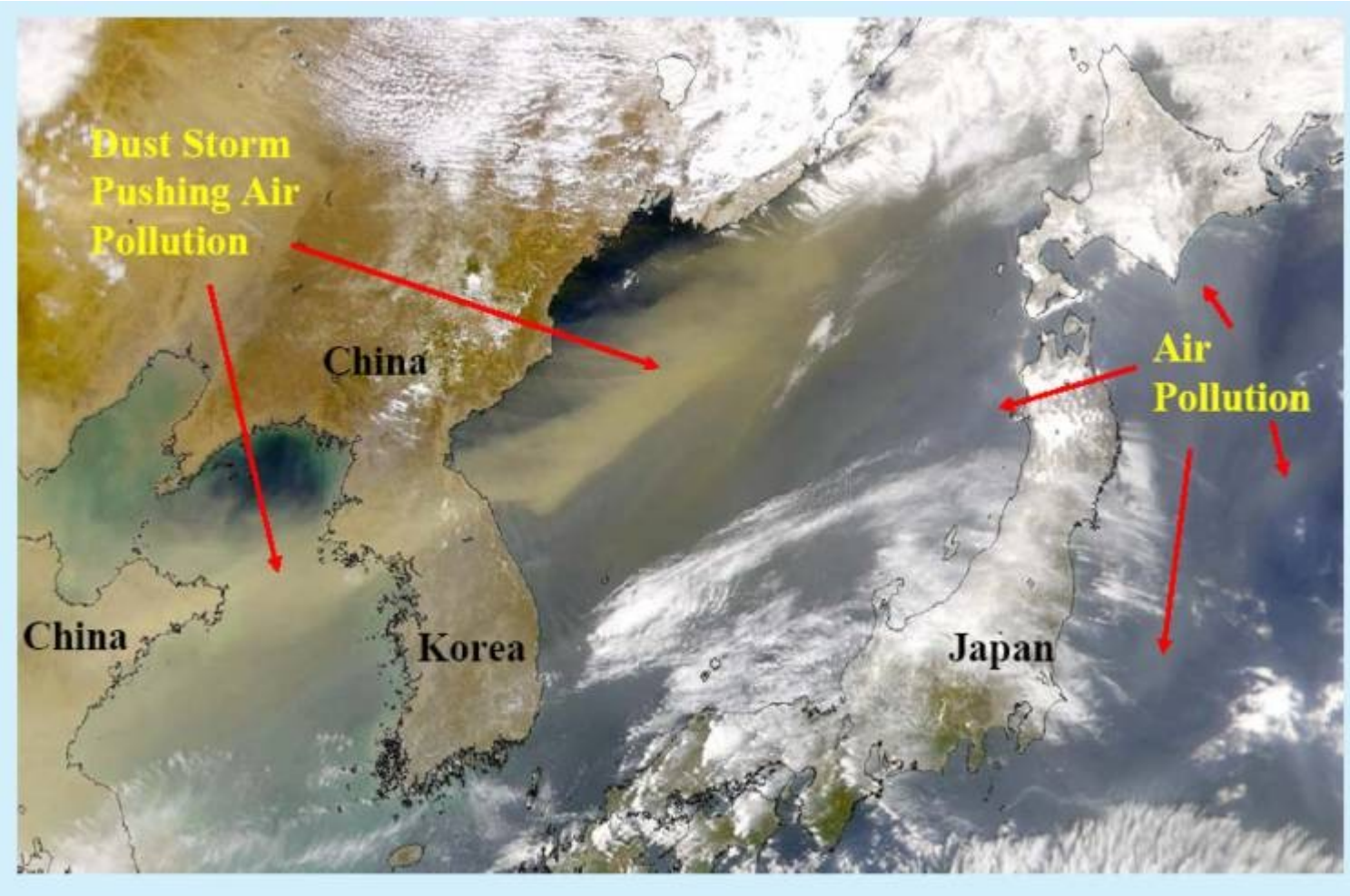
March 15, 2007

David Delene
delene@aero.und.edu
http://aerosol.atmos.und.edu

Atmospheric Particle Concentration Measurements:
Surface, Aircraft and Balloon Platforms

Importance of Aerosols



Satellite image of Asian dust storm and air pollution (April 2001).

Definitions

Aerosols

- Suspended solid or liquid matter
- Small settling velocity

Atmospheric Aerosols

- Suspended material in the Earth's atmosphere that have residence times of days, to a few weeks.
- Atmospheric Aerosols are sometimes referred to as “particles”

Atmospheric Aerosol Size Range

10^{-9}m to 10^{-5} m

(.001 µm to 10 µm or 1 nm to 10,000 nm)

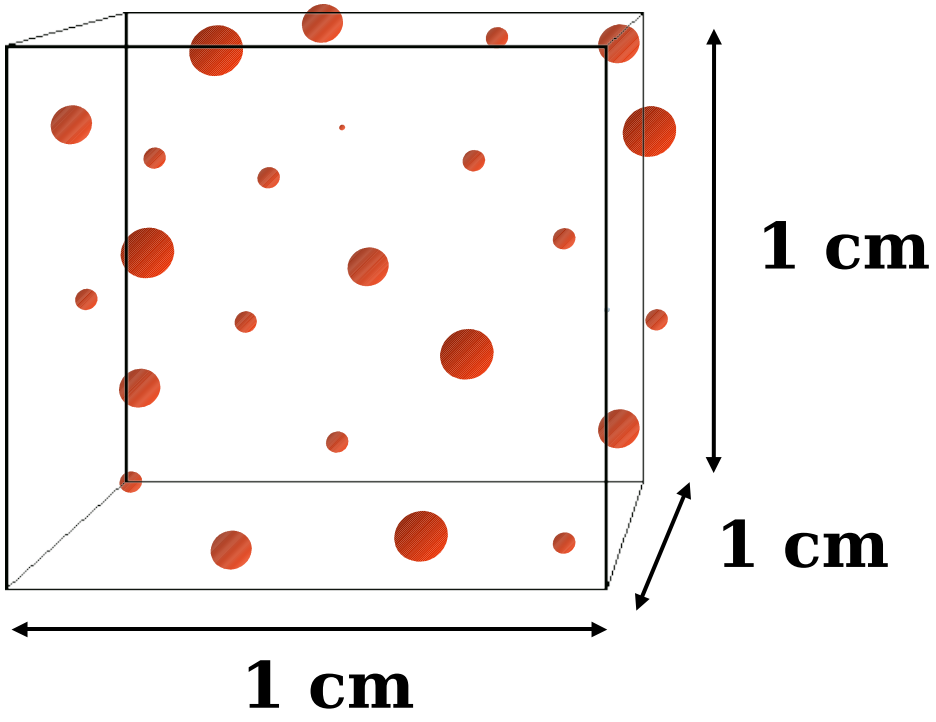
Wavelength of Visible Light?

Size of a human hair?

.001 **.01** **.1** **1**

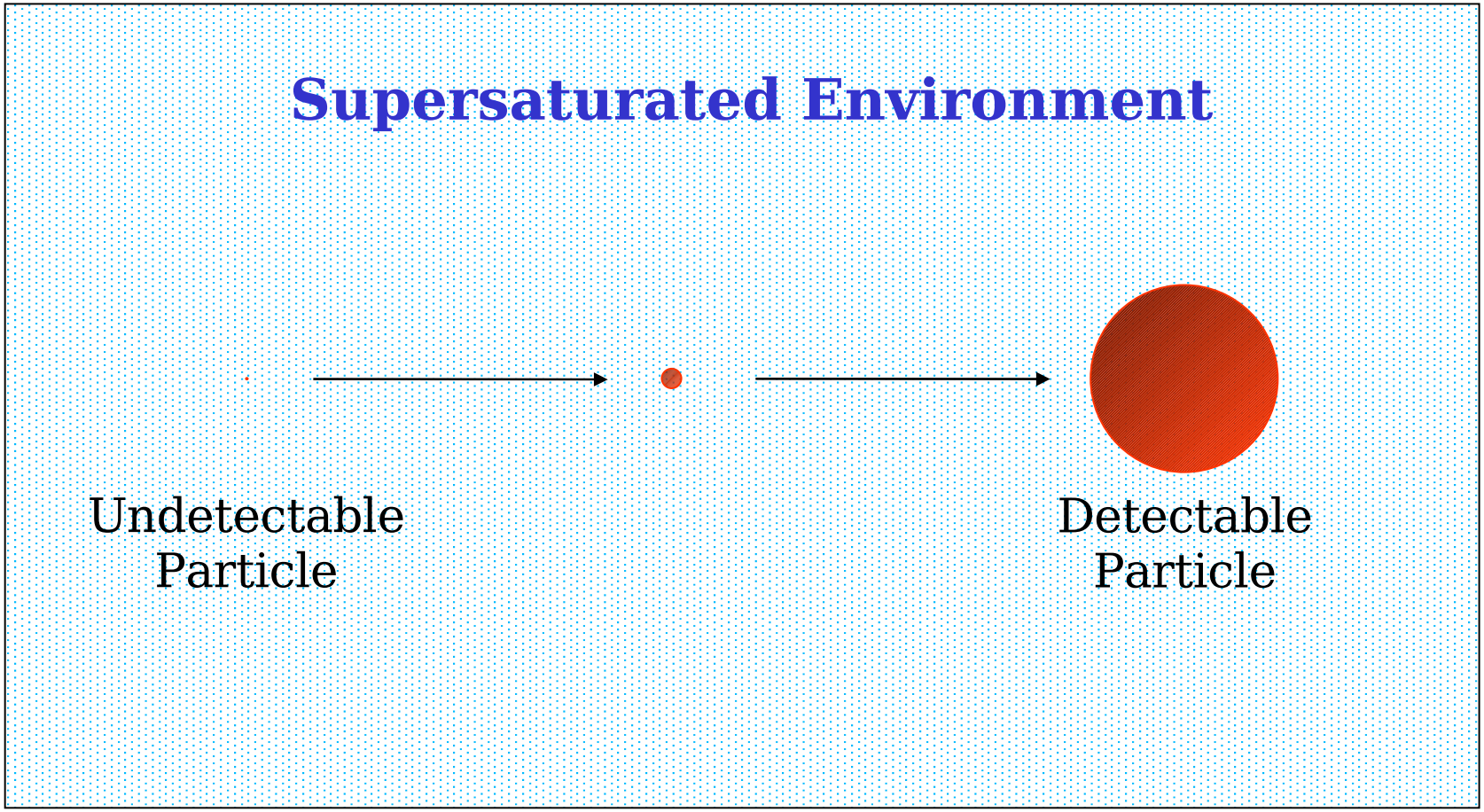
Aerosol Number Concentration

Number of Aerosols per unit Volume

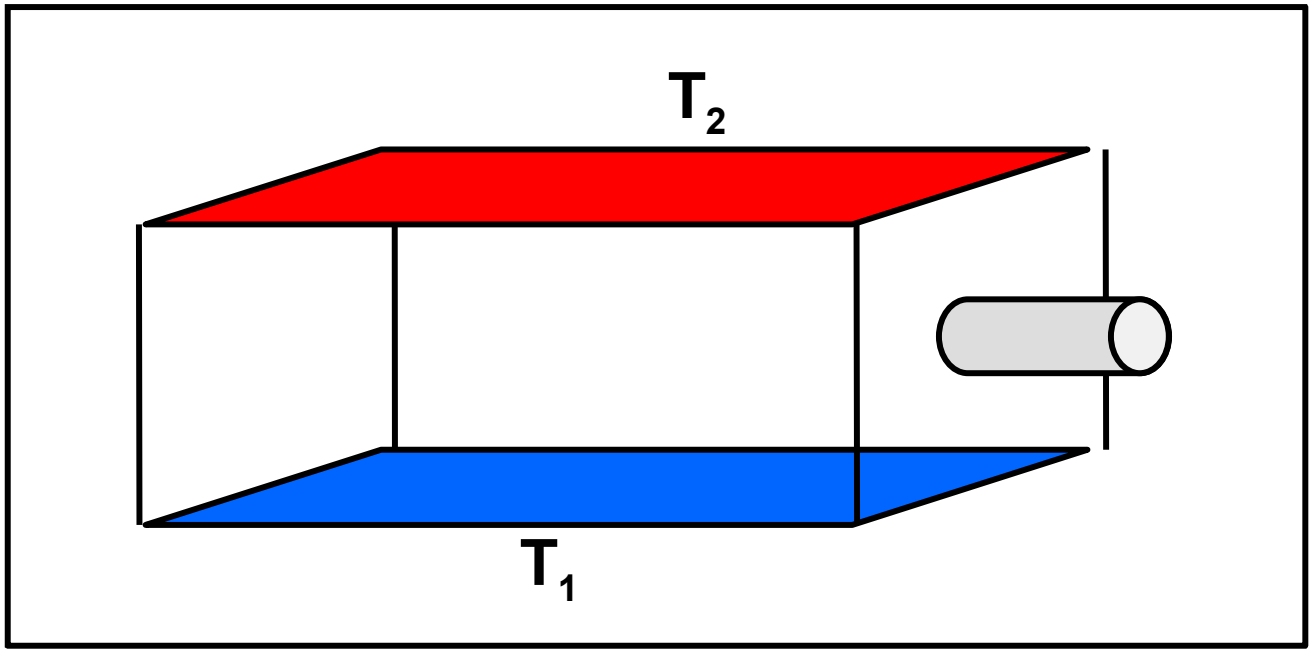


24 particles / 1 cm^3 = 24 cm^{-3}

Grow Small Aerosols to Detectable Size

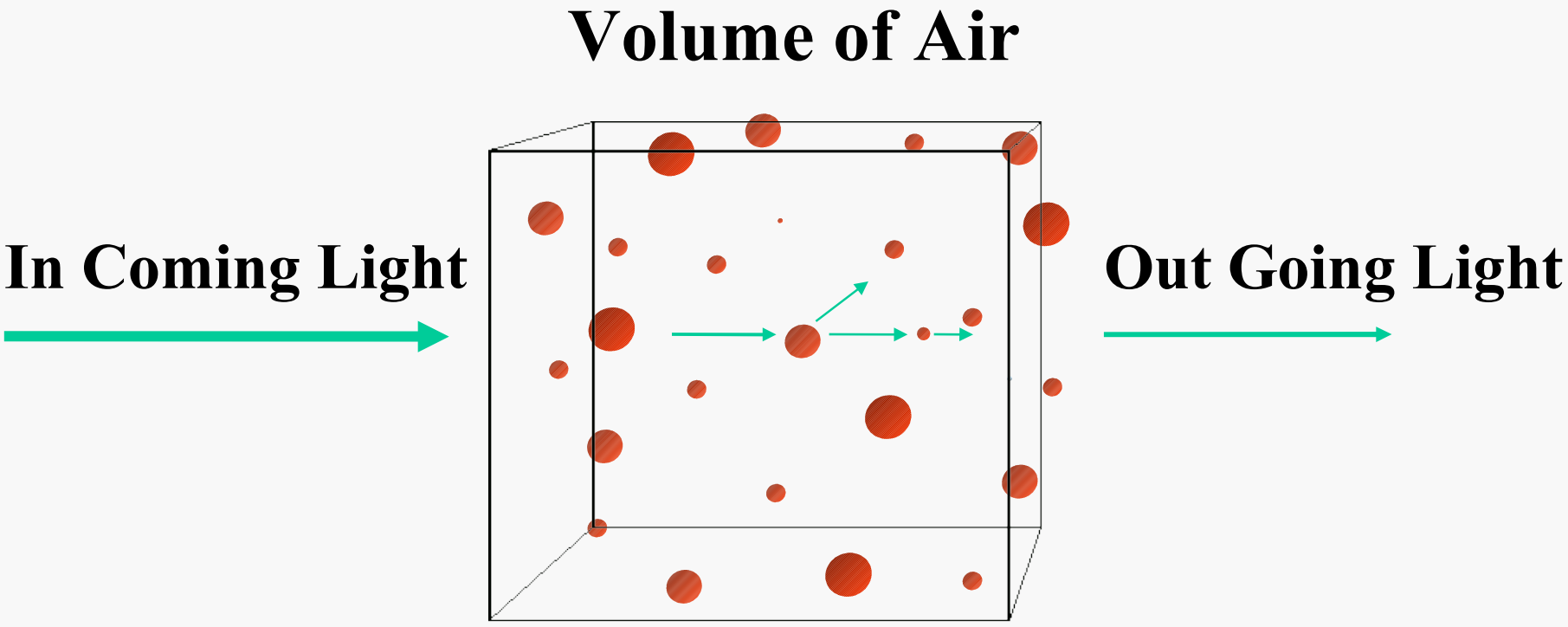


Thermal Diffusion Chamber

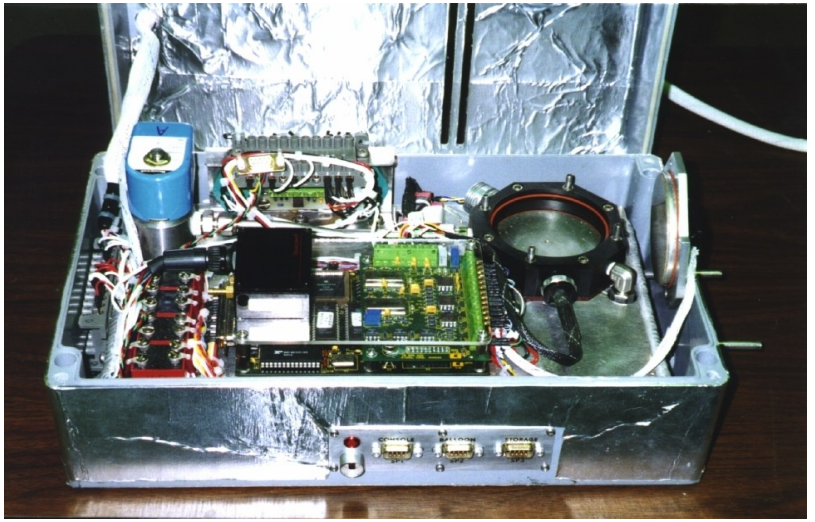


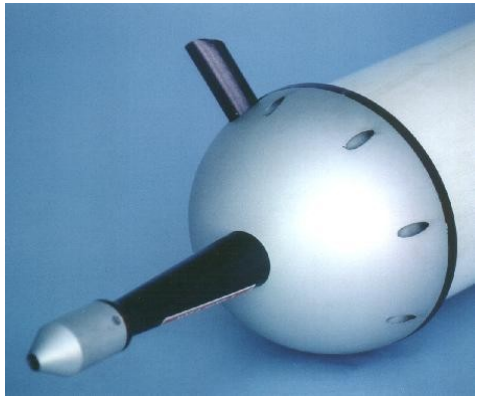
- Top Plate Warm & Moist (T_2)
- Bottom Plate Cold & Moist (T_1)
- Temperature and Water Vapor Gradients Between Plates

Light Scattering and Absorption by Aerosols



Aerosol Instruments





Surface Sites

Bondville, Illinois

Lamont, Oklahoma

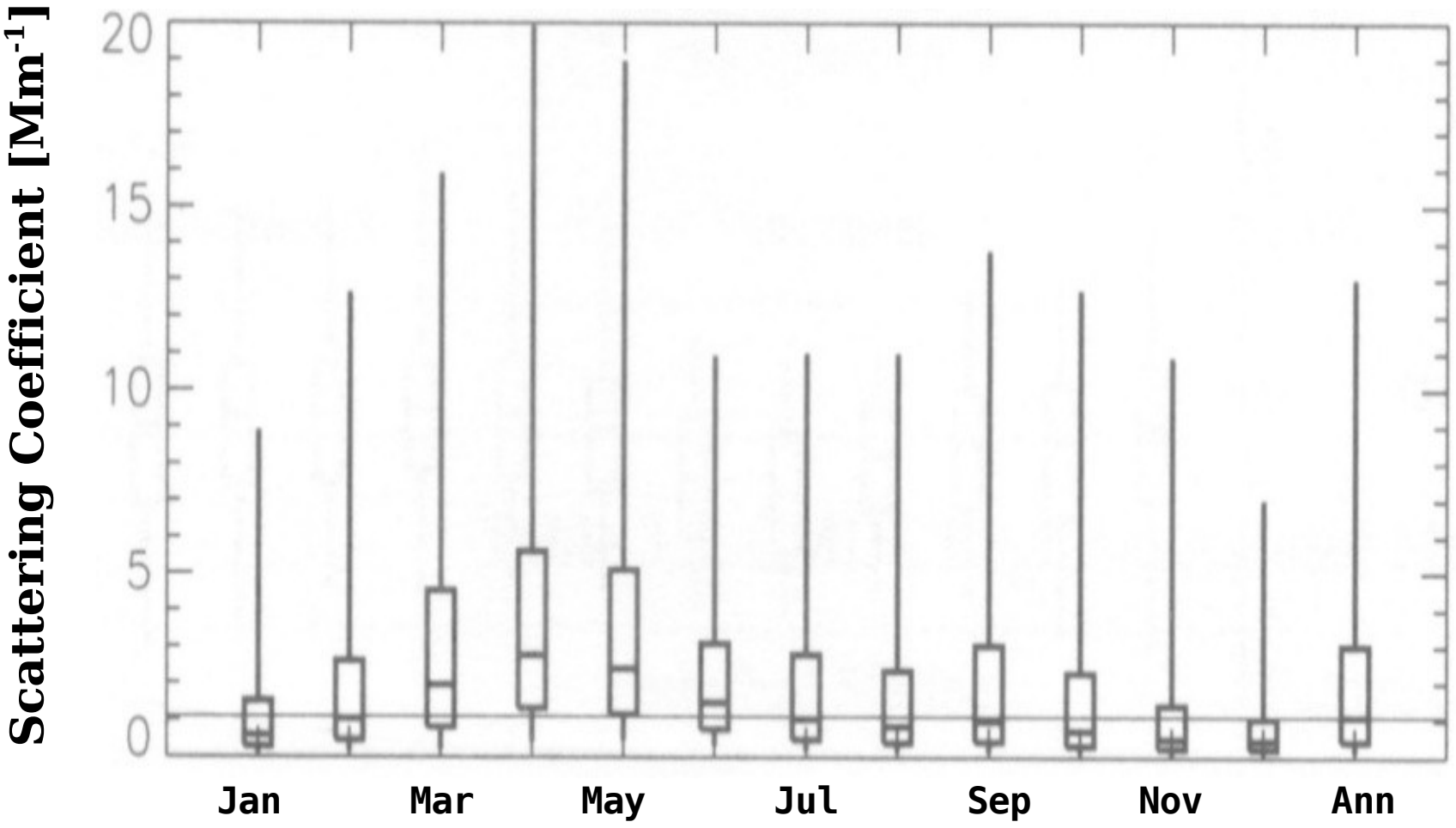
Barrow, Alaska

Mauna Loa Observatory

New Aerosol System

Dust Event at Mauna Loa (April 2000)

Seasonal Data at Mauna Loa (1974-2003)



Aircraft Aerosol System

Cessna-172XP

Aerosol Inlet

- The inlet is mounted on the starboard (right) wing of the aircraft.
- The inlet nozzle is a diffuser designed with slightly rounded leading edges.
- The nozzle orifice was sized to be isokinetic for typical C172 airspeeds (~50 m/s)
- The nozzle and inlet tube are constructed of anodized aluminium
- Large diameter conductive tubing passes aerosols to the instruments.

Aircraft Aerosol System

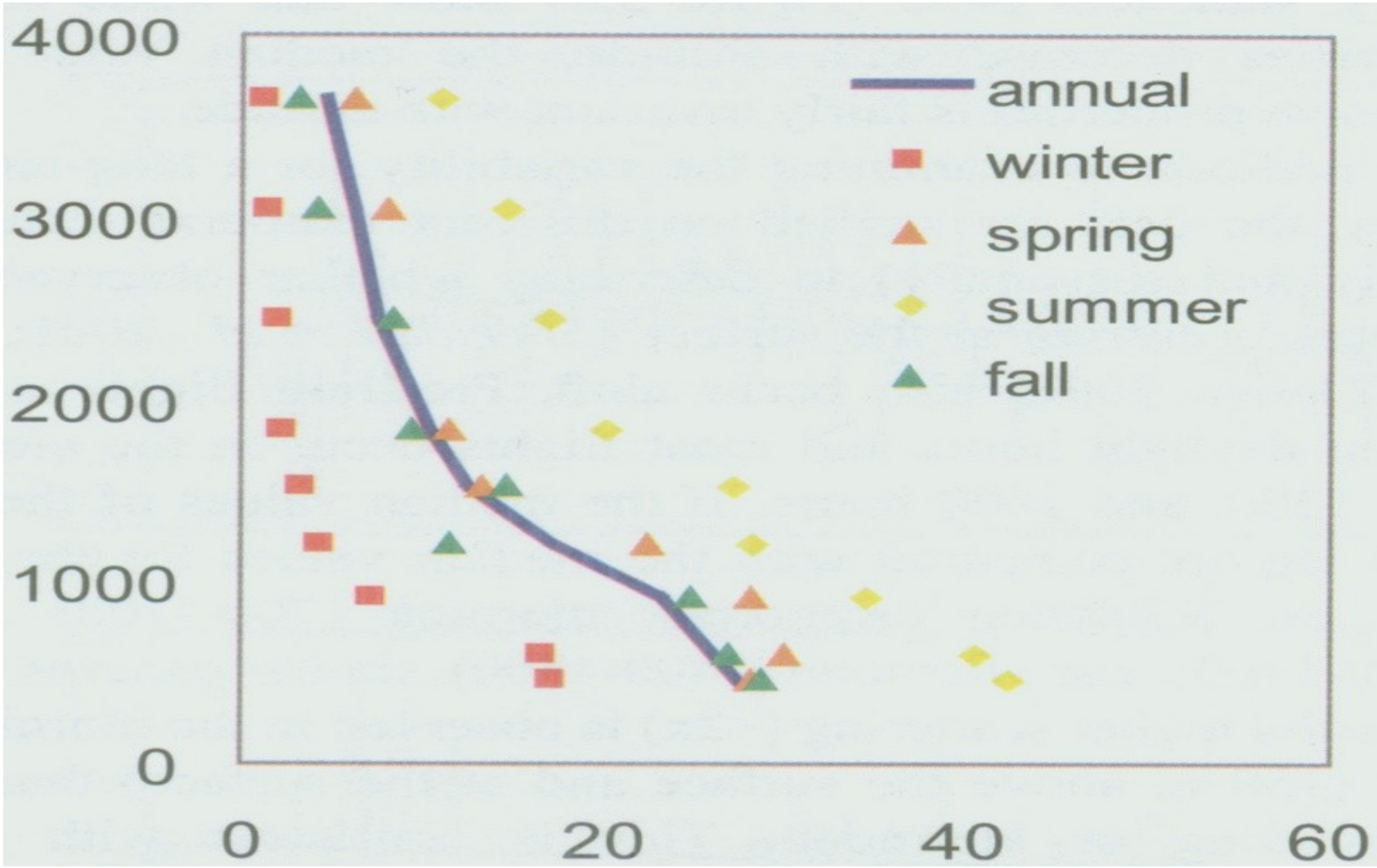
Front (Starboard) View of Rack

View of Rack from Rear of Plane

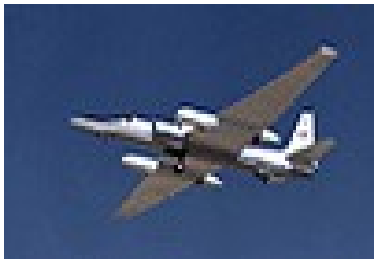
Back (port) View of Rack

- The aerosol instrumentation payload is bolted down inside the Cessna.
- Instruments rack consists primarily of a TSI nephelometer and a particle light absorption photometer.

Aircraft Profile Summary above Lamont, Oklahoma



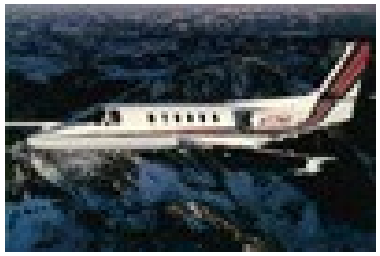
Crystal-FACE Research Aircraft



ER-2

Proteus

WB-57



Citation

P-3

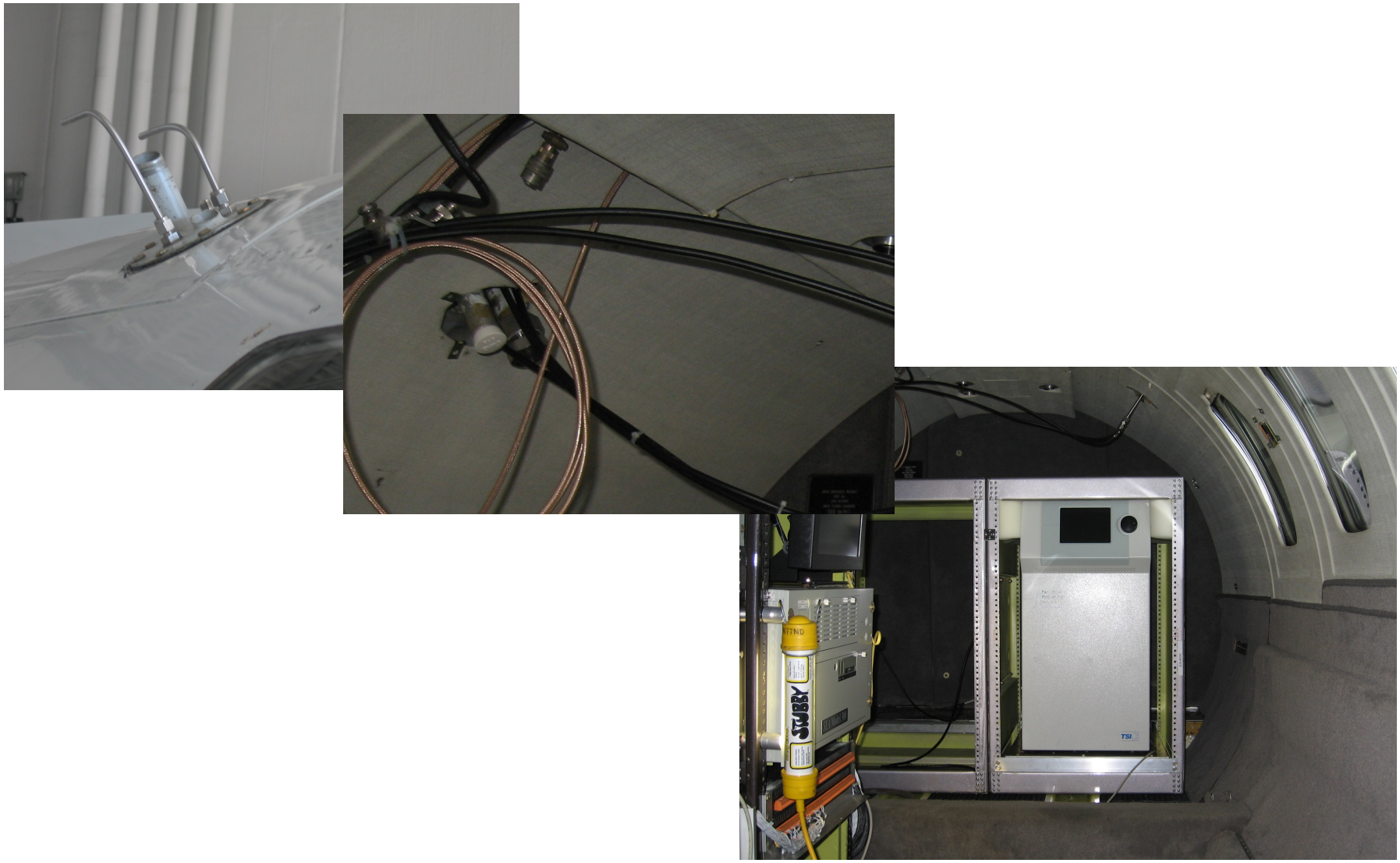
Twin Otter

- Crystal-FACE is a measurement campaign designed to investigate tropical cirrus cloud physical properties and formation processes.
- Understanding the production of upper tropospheric cirrus clouds is essential for the successful modeling of the Earth's climate.

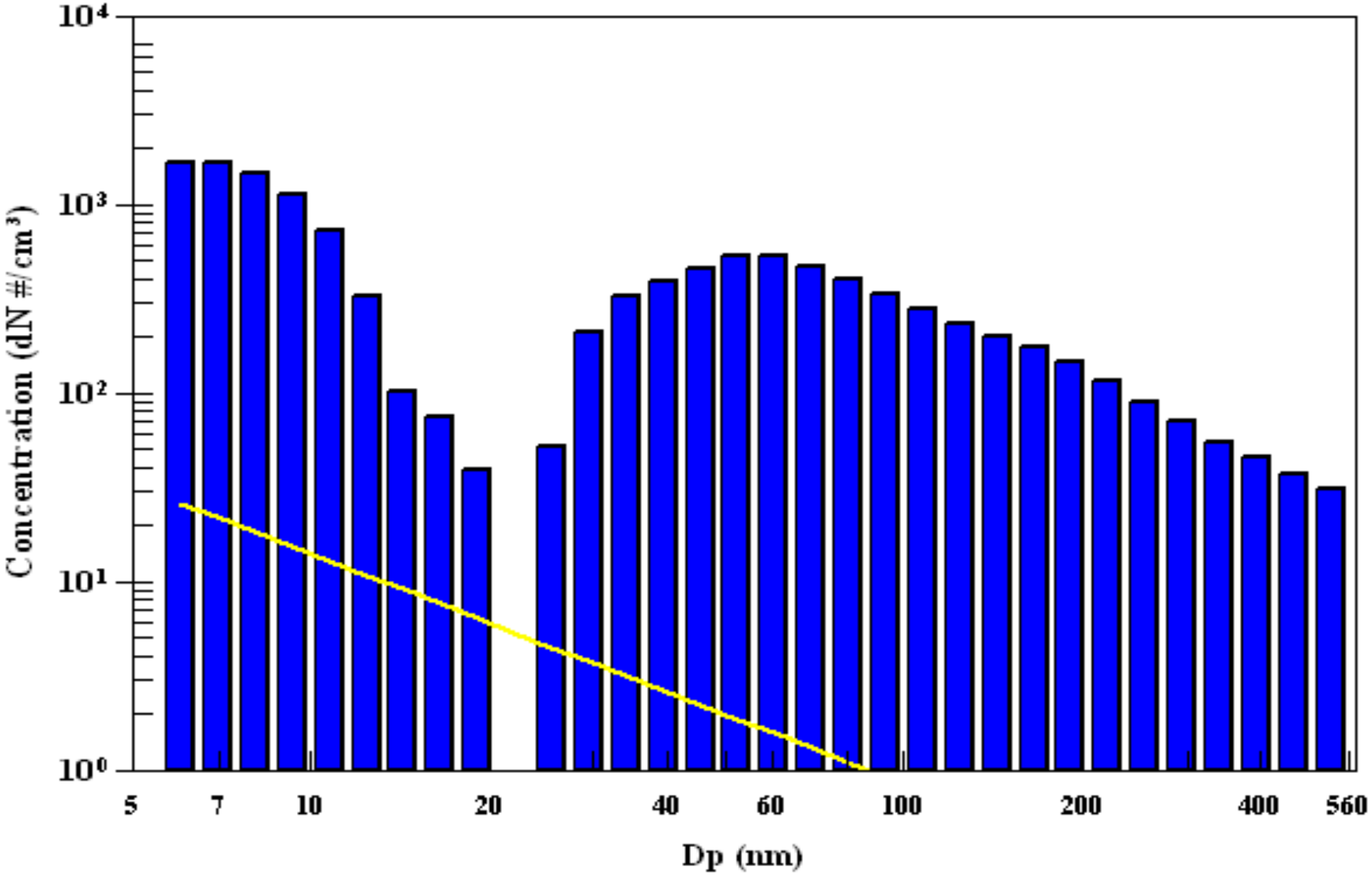
Fast Mobility Particle Sizer Measurement Features

- Particle measurements between 5.6 to 560 nm in 32 channels.
- Particle size distributions with one-second resolution.
- Particle concentration range across more than 4 orders of magnitude.
- Self contained and runs on 120 volts AC power.
- Data collection and analysis software.

Installation of the FMPS in the UND Citation Research Aircraft



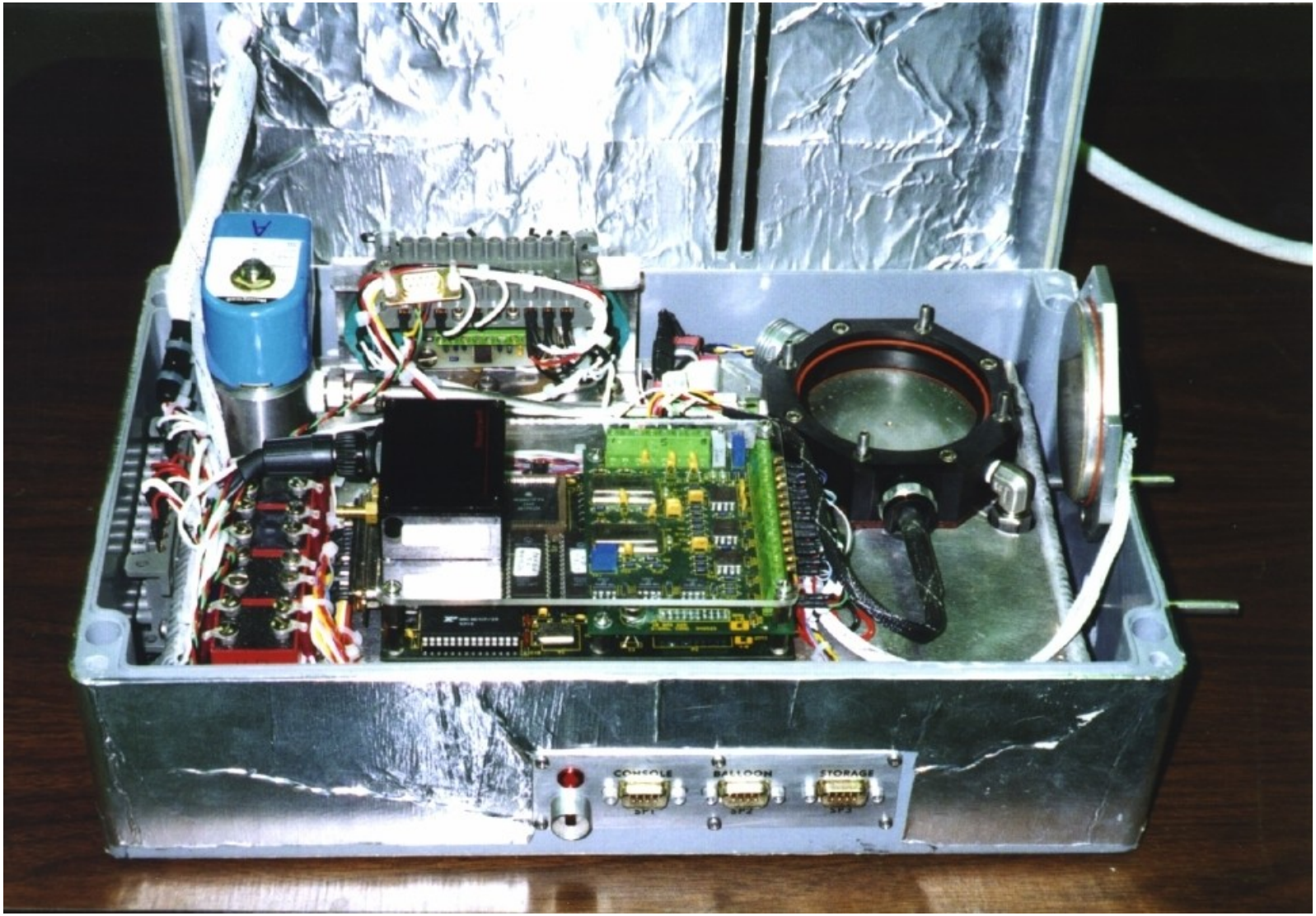
FMPS Measured Size Spectrum on September 2, 2005 in Grand Forks



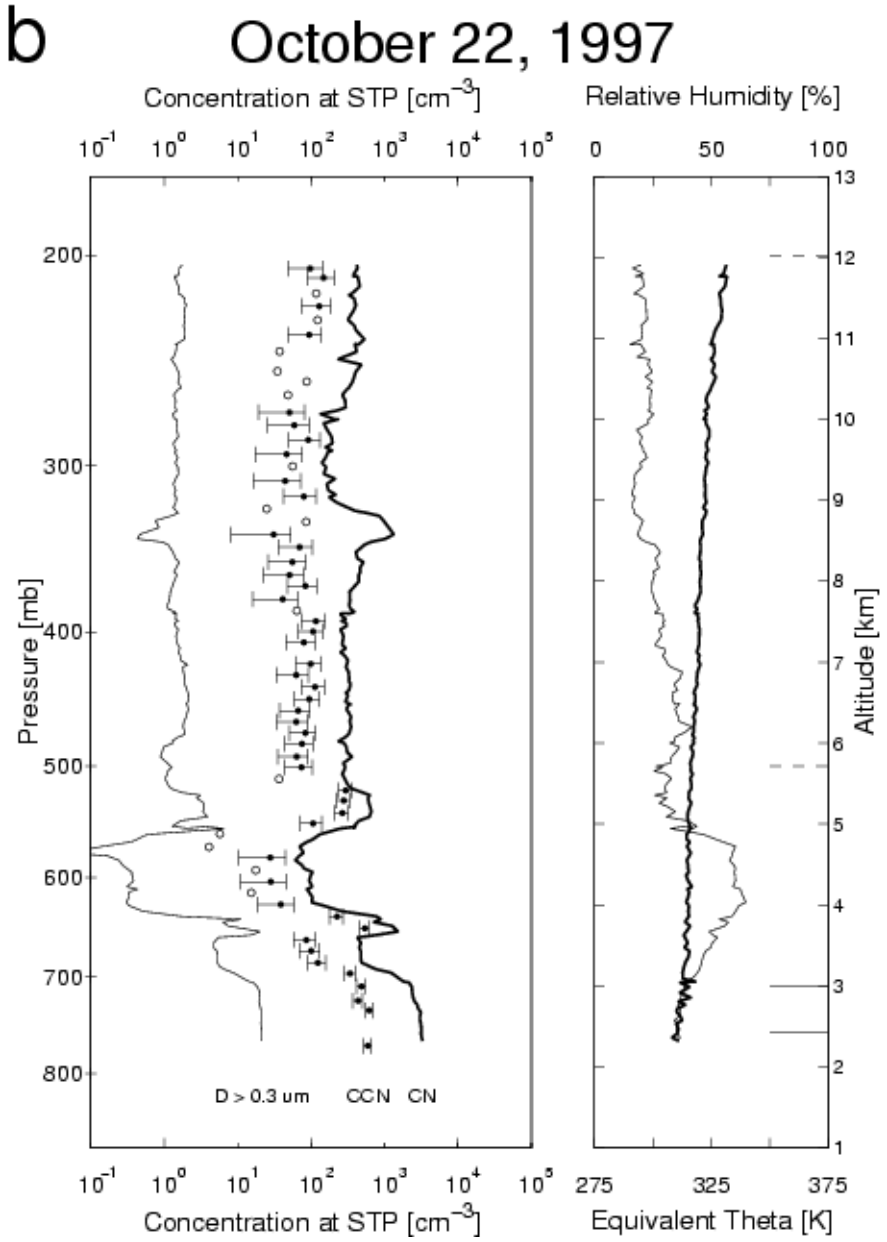
New Zealand Balloon Launch

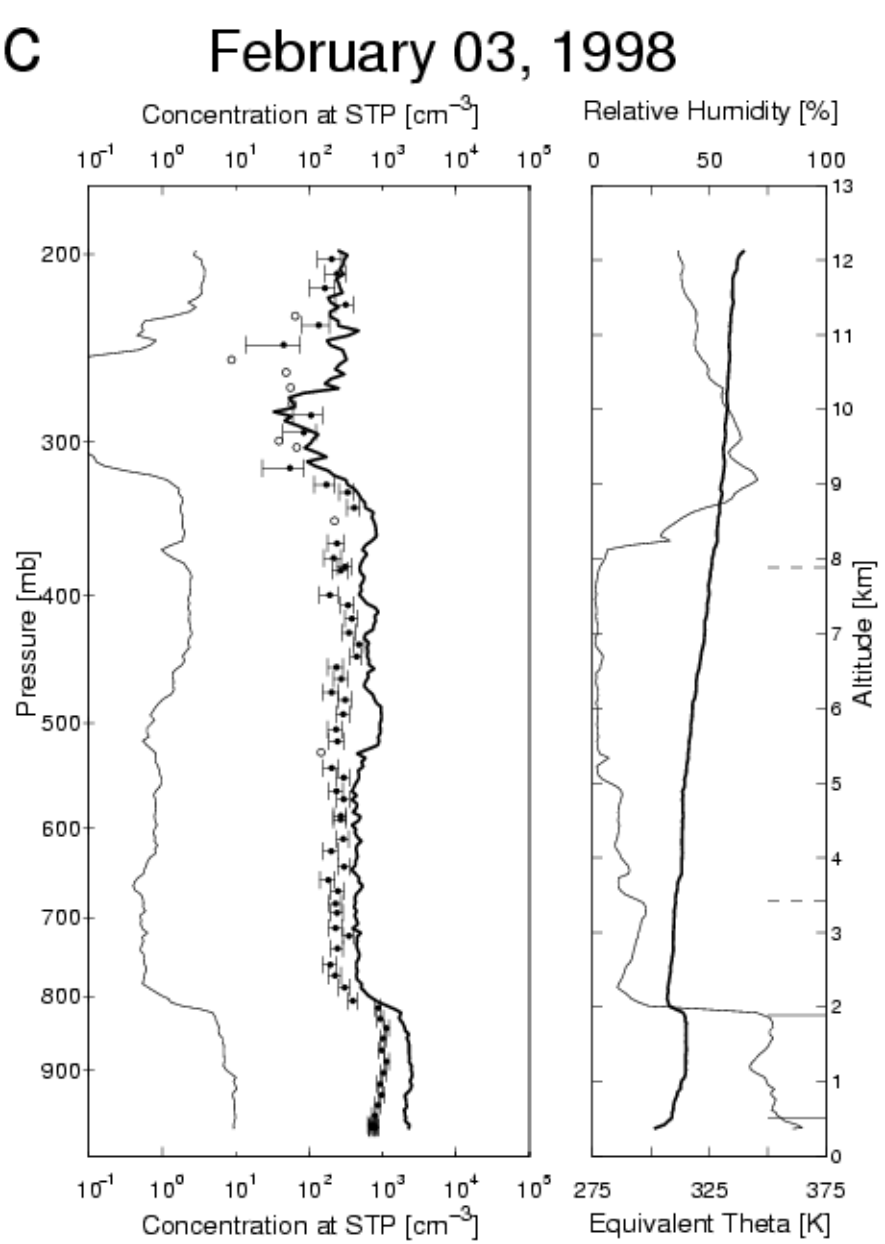
Filling Balloon for Launch

University of Wyoming Balloon-borne Cloud Condensation Nucleus Counter



Balloon-borne Aerosol Profiles





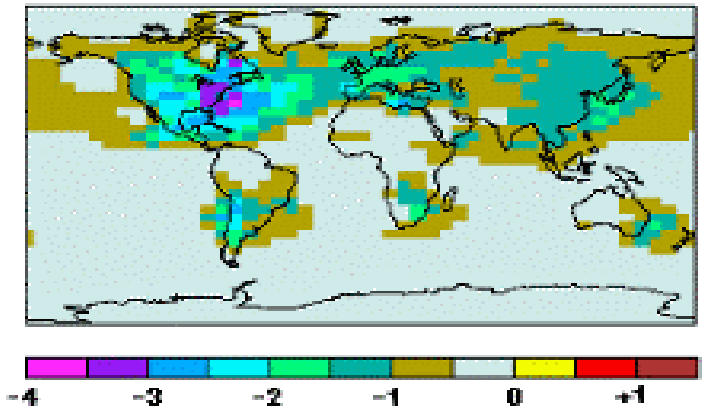
Summary

- Aerosols are suspended particles in the atmosphere that affect the scattering and absorption of sunlight and affect cloud and participation process.
- To understand atmospheric aerosols require measurements from surface, aircraft and balloon platforms.
- Conducting measurements to learn about the atmosphere can be a lot of fun!

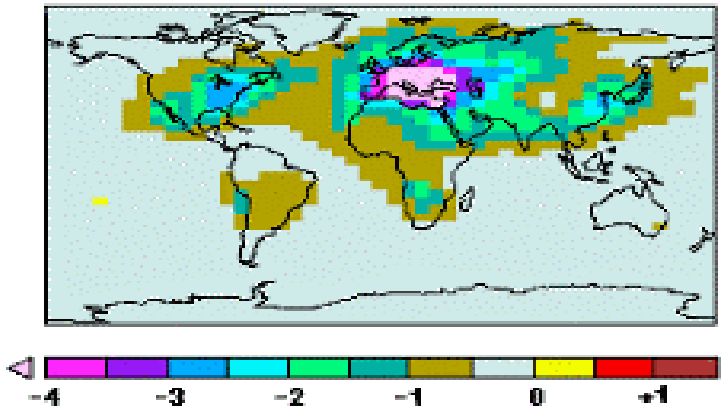
Any Questions?

Importance of Aerosols

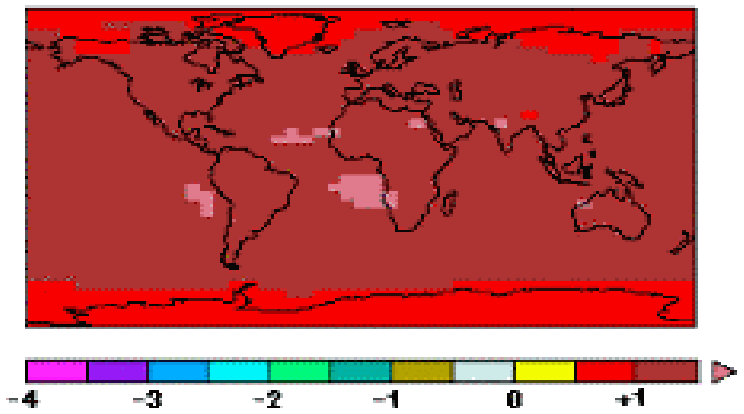
Indirect Forcing



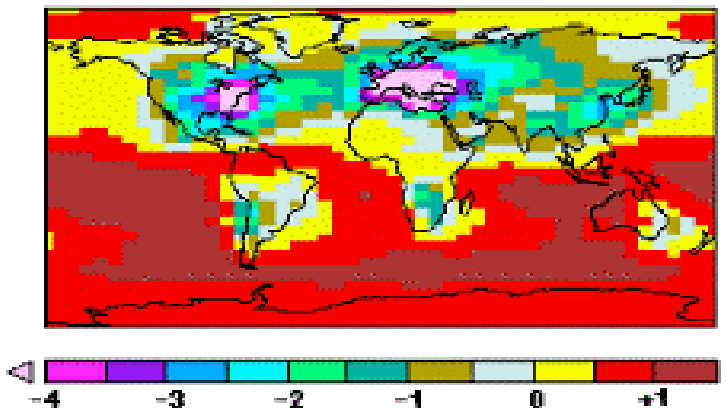
Direct Forcing



Carbon Dioxide Forcing

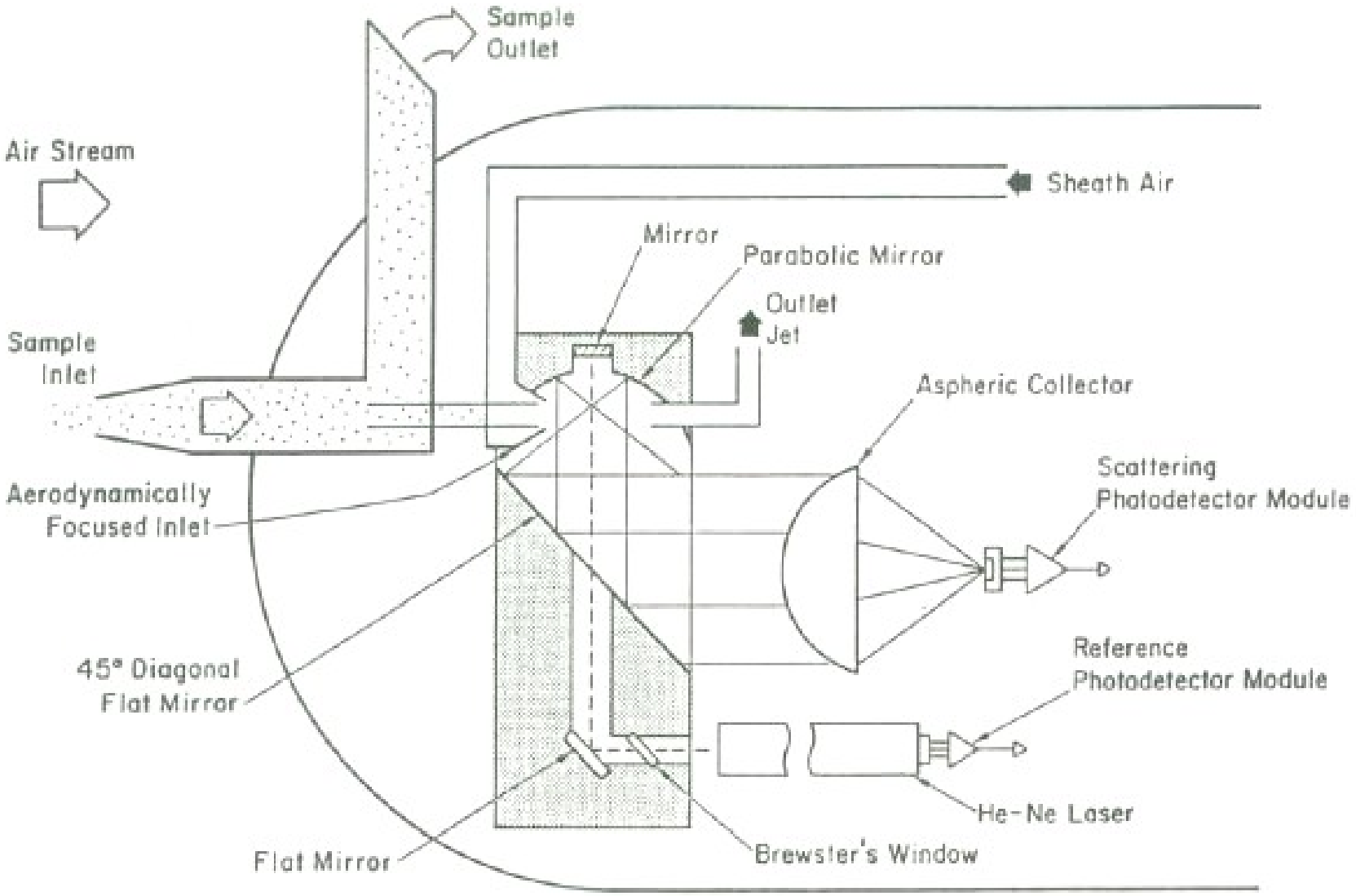


Total Forcing

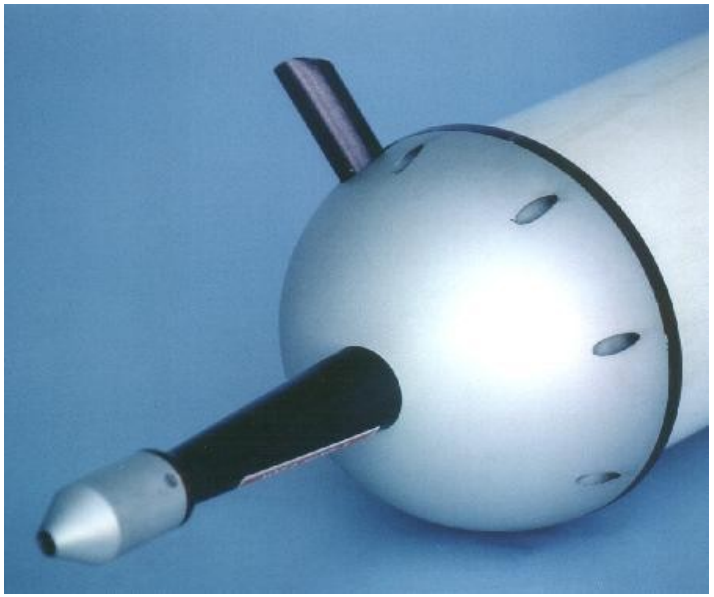


Climate forcing predicted from the Lawrence Livermore National Laboratory Global Aerosol Model [Catherine C. Chuang and Joyce E. Penner].

Passive Cavity Aerosol Spectrometer Probe



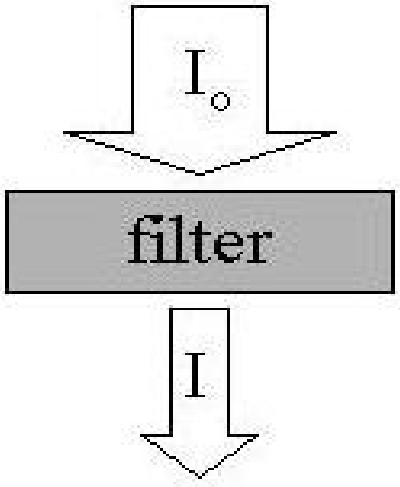
Optical Particle Counter



Operating Principles

- Detects single particles and sizes them by measuring the intensity of light that the particle scatters when passing through a light beam.
- The light beam can be either from a white light source or a laser.
- The size of the particle is determined by measuring the light scattering intensity and using Mie scattering theory to relate this intensity to the particle size.

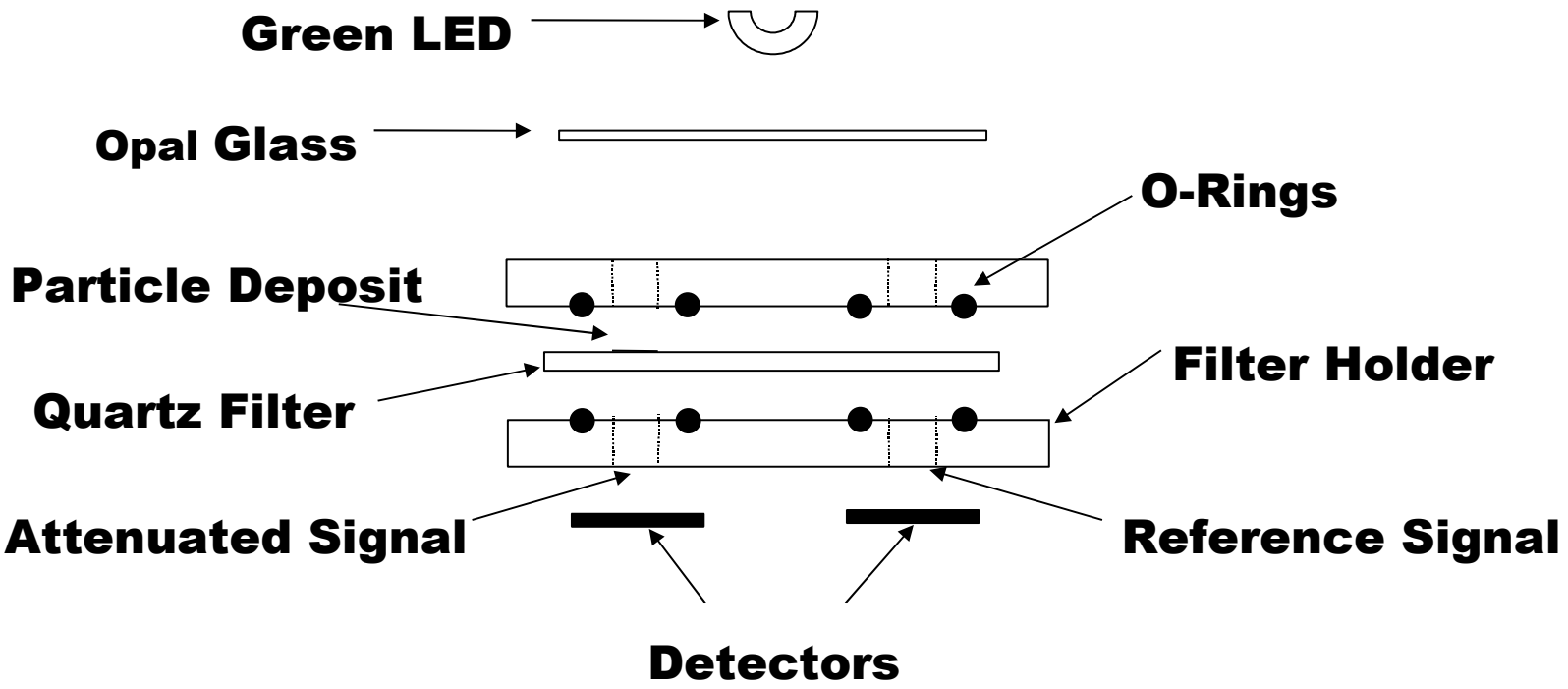
Particle Soot Absorption Photometer



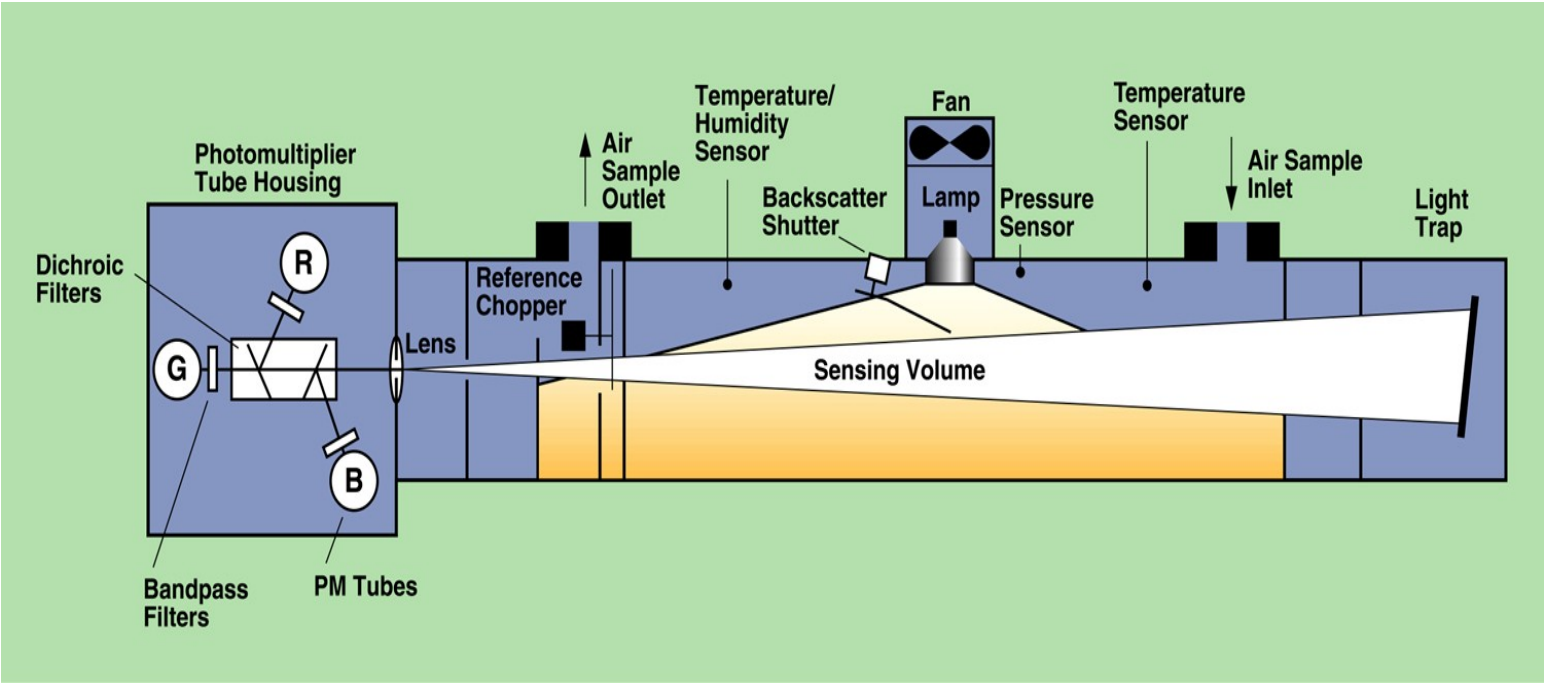
Beers Law

$$A=\ln(I_o / I)$$

A is the absorbance
I is the intensity of light transmitted
$\mathbf{I_o}$ is the light intensity before passing through the filter.



Integrating Nephelometer



TSI 3563 Nephelometer schematic courtesy of TSI Incorporated

Beer-Lambert Law

$$I / I_o = e^{(- \tilde{A} x)}$$

I_o = intensity of light source

I = intensity of light after passing through atmospheric path

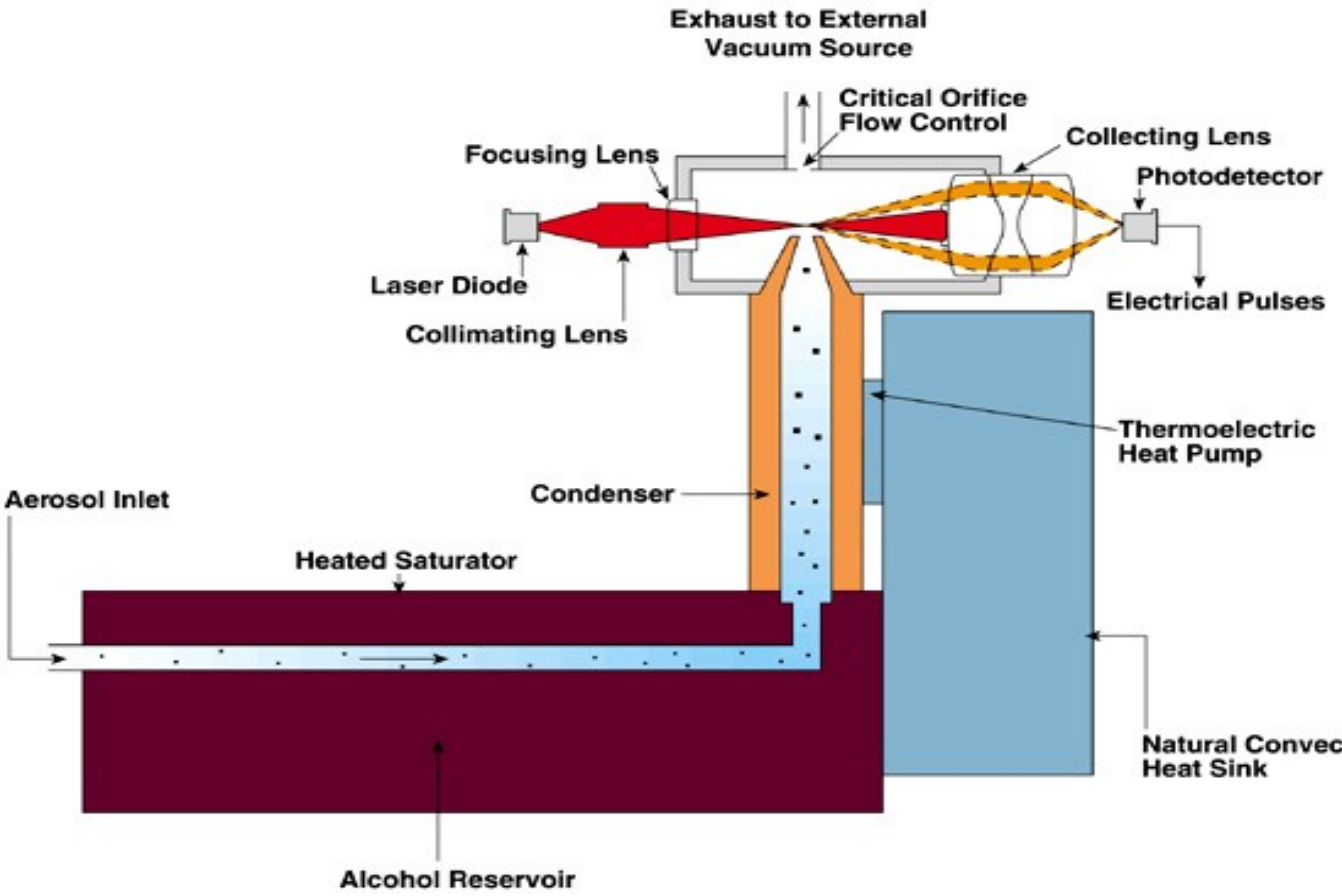
x = thickness of medium through which light passes

$\tilde{A}$ = total extinction coefficient (scattering + absorption)

Instrumentation Based Aerosol Definitions

- **Ultrafine Aerosols (UF)**
  Aerosols larger than 3 nm diameter.
- **Condensation Nuclei (CN)**
  Aerosols larger than 10 nm diameter.
- **Optical Aerosols ($D_{0.3}$)**
  Aerosols larger than 0.3 μm diameter.
- **Cloud Condensation Nuclei (CCN)**
  Nuclei on which cloud droplets form.
- **Ice Nuclei (IN)**
  Nuclei on which ice crystals form.

Condensation Nucleus Counter



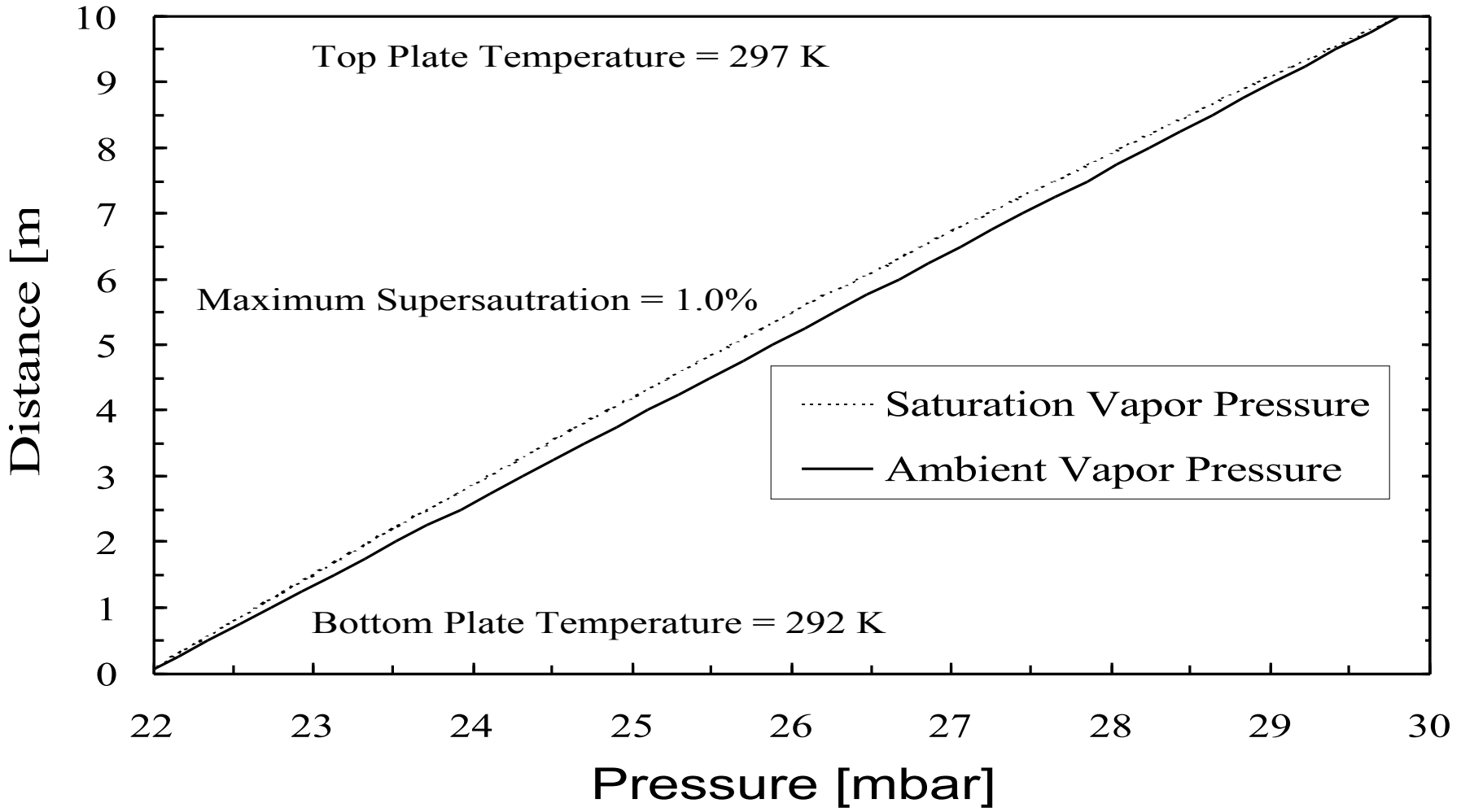
Alcohol vapor condenses onto particles which create droplets large enough to be detected one at a time by an optical particle counter. Upon entering the instrument, the air sample passes through a saturation block where alcohol evaporates saturating the flow. The air sample next enters a condenser tube which cools the air sample. Cooling of the air sample creates a supersaturated environment and the alcohol condenses onto particles, regardless of particle composition.

Vapor Pressure

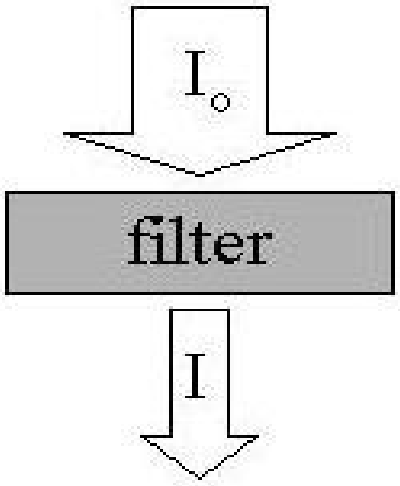
Ambient vapor pressure is linear from top to bottom.

Saturation vapor pressure is a curve from top to bottom.

A supersaturation exists between top and bottom



Particle Soot Absorption Photometer



Beers Law

$$A=\ln(I_O / I)$$

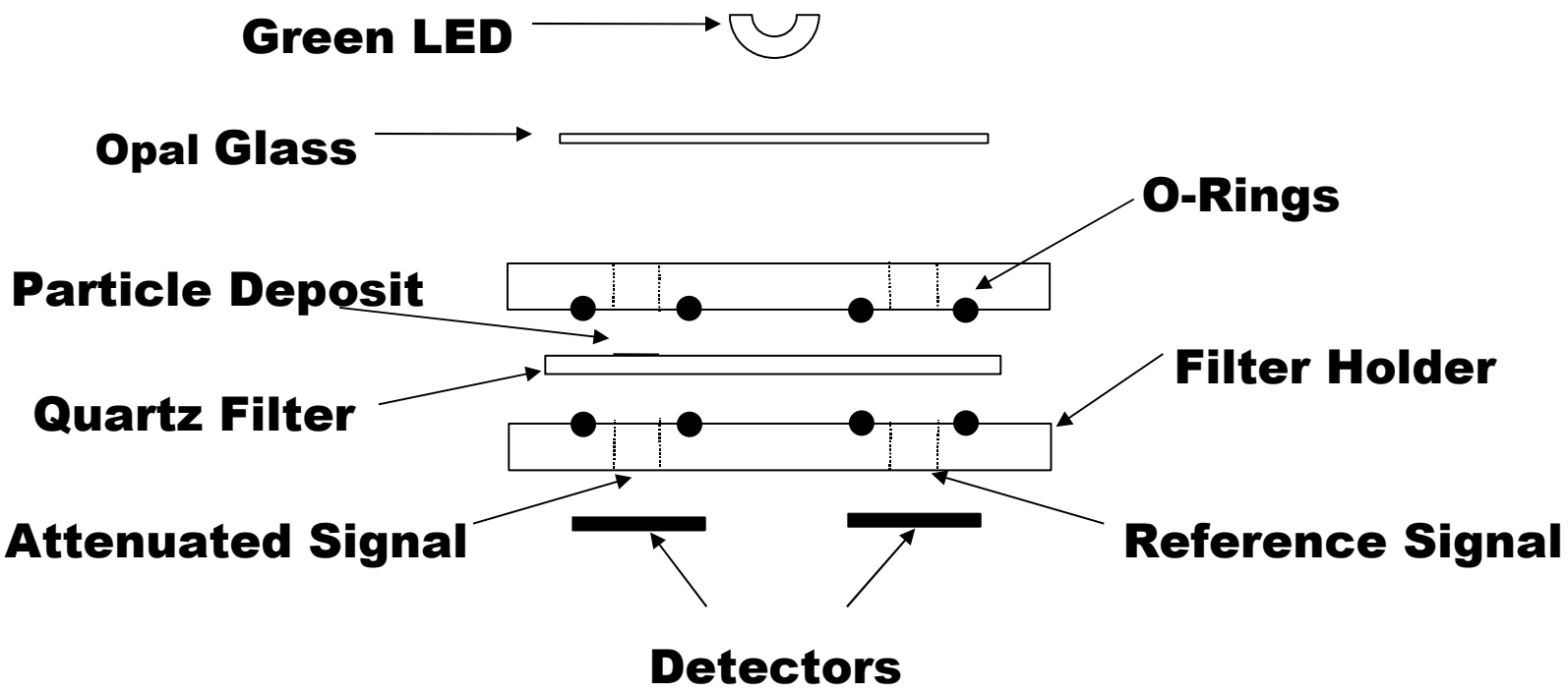
A is the absorbance
I is the intensity of light transmitted
$\mathbf{I_o}$ is the light intensity before passing through the filter.

Absorption coefficient is given by:

$$b_{ap} = (\text{area/volume})*\ln(I_o/I)$$

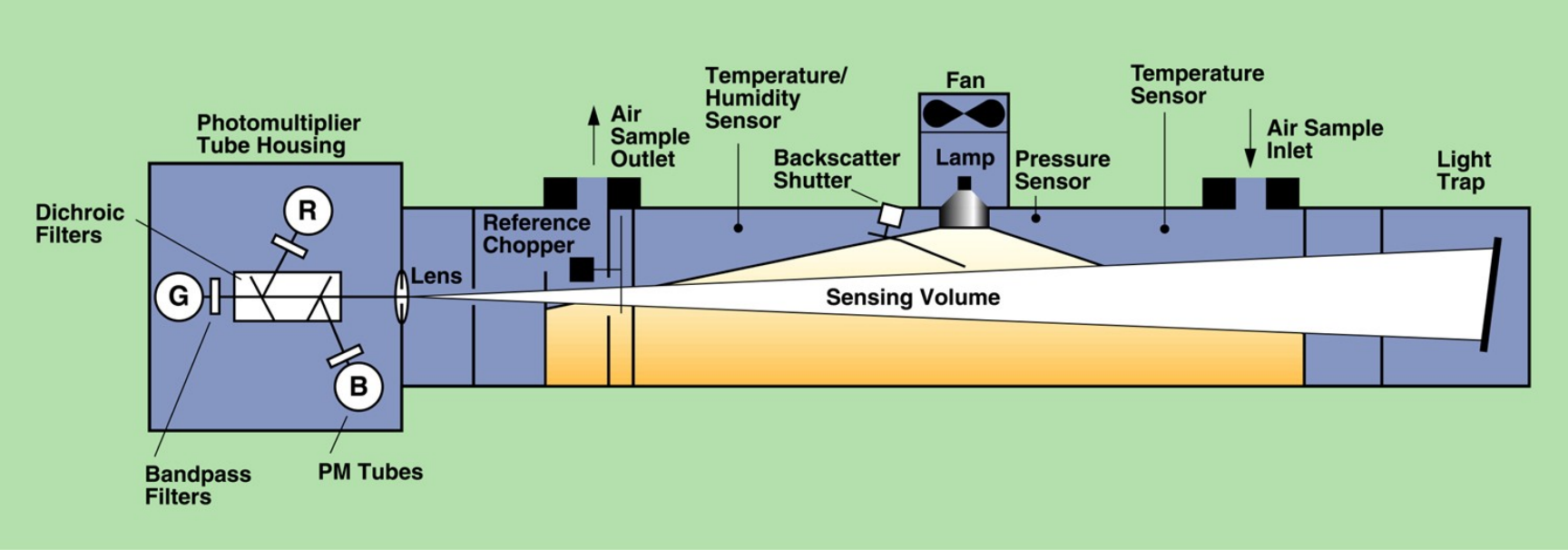
$\mathbf{b_{ap}}$ is the absorption coefficient [m^{-1}]
Area is the area of the sample spot [m^2]
Volume is the volume of air sampled in averaging period [m^3]
I is the average filter transmittance for averaging period
$\mathbf{I_o}$ is the average filter transmittance for averaging period

Particle Soot Absorption Photometer



- Principle of operation is to measure the change in light transmission through a filter on which particles are collected.
- Calibration uses a reference absorption determined as the difference between light extinction and light scattering.
- Instrument exhibits a significant response to nonabsorbing aerosols and overestimates absorption due to suspended particles by about 20-30%.

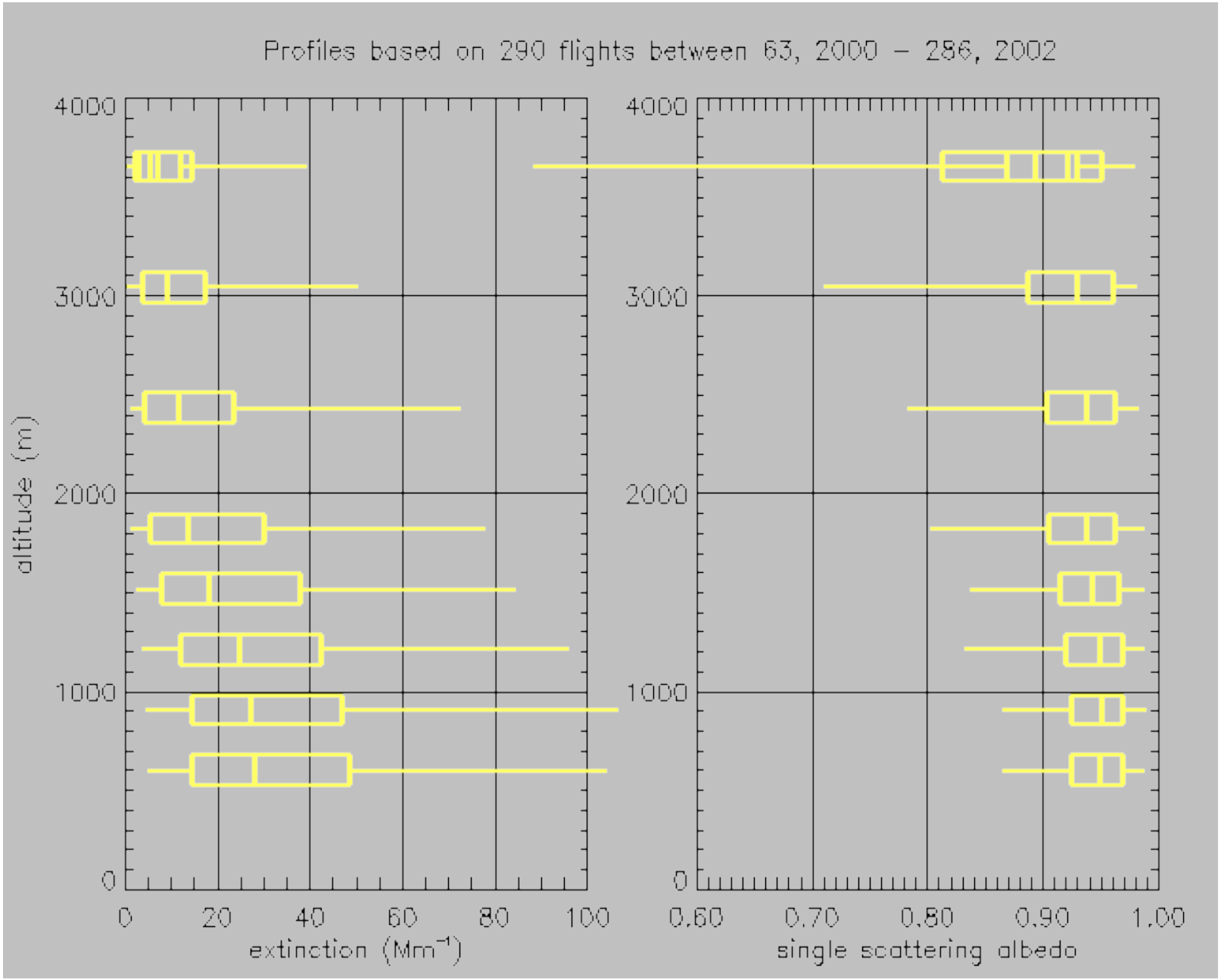
Integrating Nephelometer



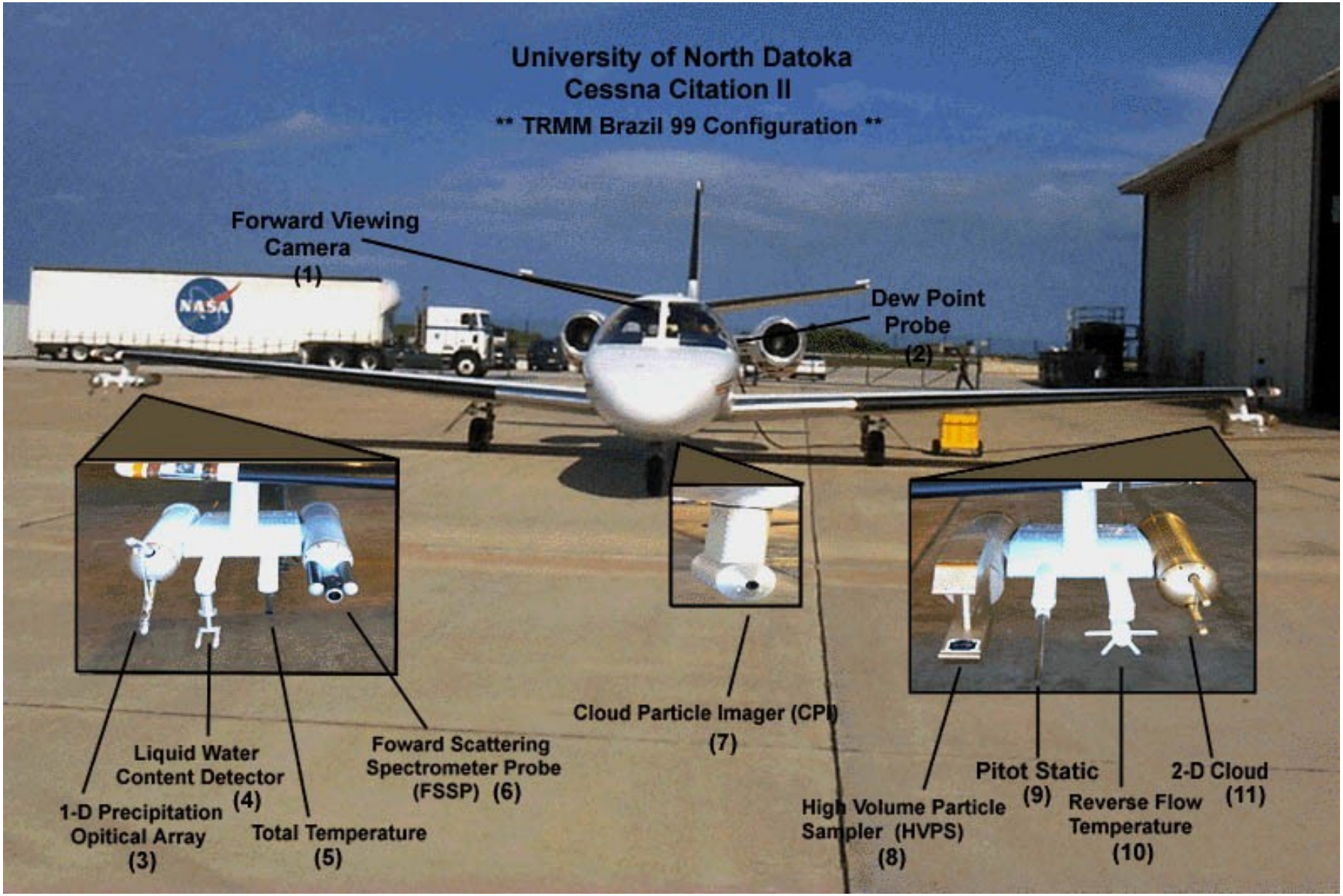
TSI 3563 Nephelometer schematic courtesy of TSI Incorporated

- The Nephelometer detects aerosol scattering by measuring total light scattered and subtracting light scattered by the air, the instrument walls and the detector background noise.
- Calibration is done by measuring two reference gases with know scattering values, typically air and CO_2.
- The nephelometer measures from 7-170^o scatting angles and the backsctter shutter allows blocking of angles from 7-90^o. Measurements are corrected to the 0-180^o and 0-90^o range.

Aircraft Profile Summary

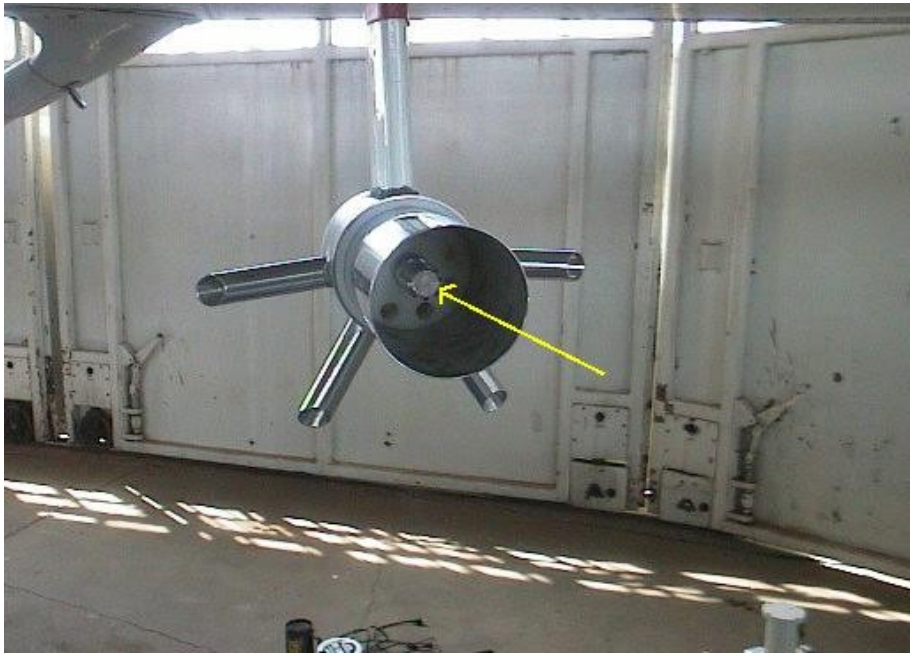


Wing Mounted Instruments



Aircraft Aerosol System

Temperature and Relative Humidity Sensor



The temperature/Relative Humidity sensor (Humicap, Vaisala Inc.) is mounted on the outside of the aircraft on the the bottom of the right (starboard) wing. The sensor is mounted inside a counter-flow inlet