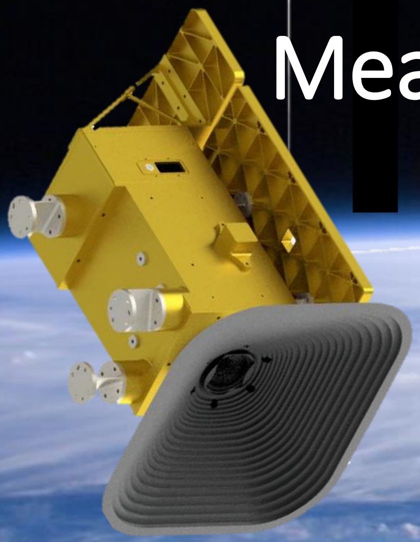
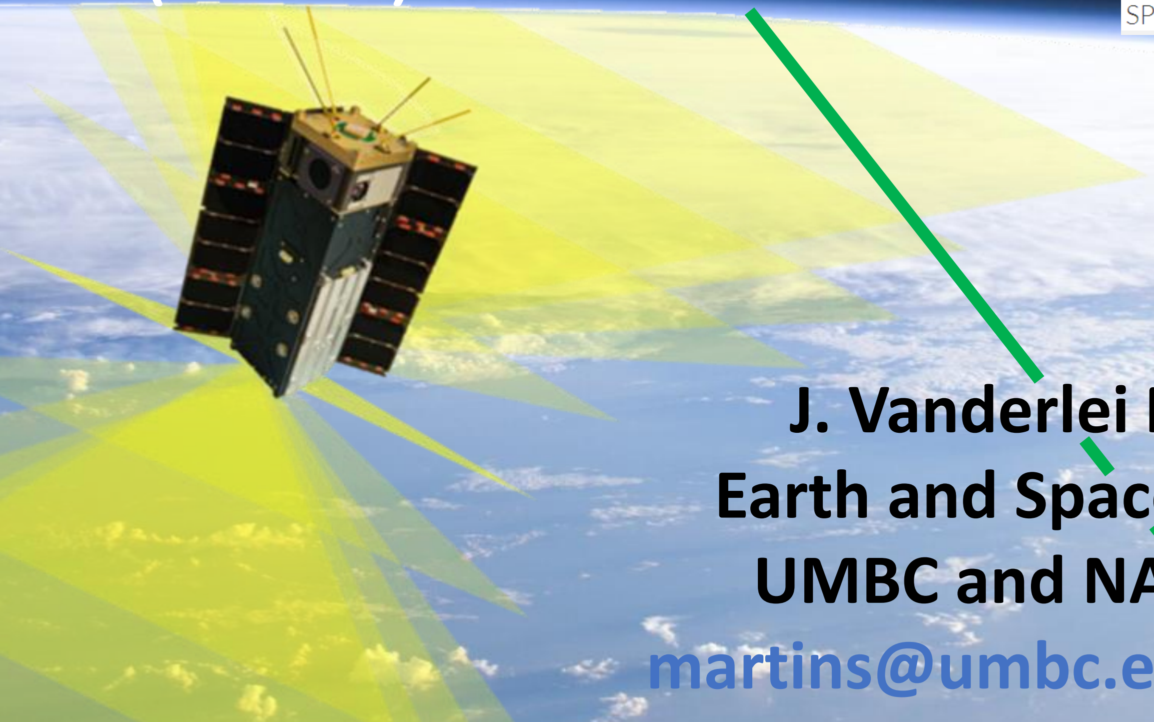
Remote Sensing tools from Ground, Airborne and Space: Measuring radiation and designing instruments (Part II)

SPSAS on Atmospheric Aerosols





J. Vanderlei Martins
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UMBC and NASA GSFC
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Link for data and posters:

- https://bit.ly/2SRz23

Discussion on analysis and Results of the SPSAS Field Measurement's Day

SPSAS on Atmospheric Aerosols

Prof. J. Vanderlei Martins
Earth and Space Institute – UMBC
University of Maryland Baltimore County

SPSAS on Atmospheric Aerosols

Field day Poster Session

- Objective: Share your experience with your colleagues and learn from each other.

“This was a learning experience more than a scientific experiment”

- Student teams will prepare a poster with results from their experiment to present to the whole group of students. We will have a poster session in the last Thursday of the event.
- You should show pictures, diagrams, experimental setup, plots, results, data interpretations, comparisons, conclusions.
- Poster format: A1 (59.4 x 84.1 cm)

Experiences from the Field Day:

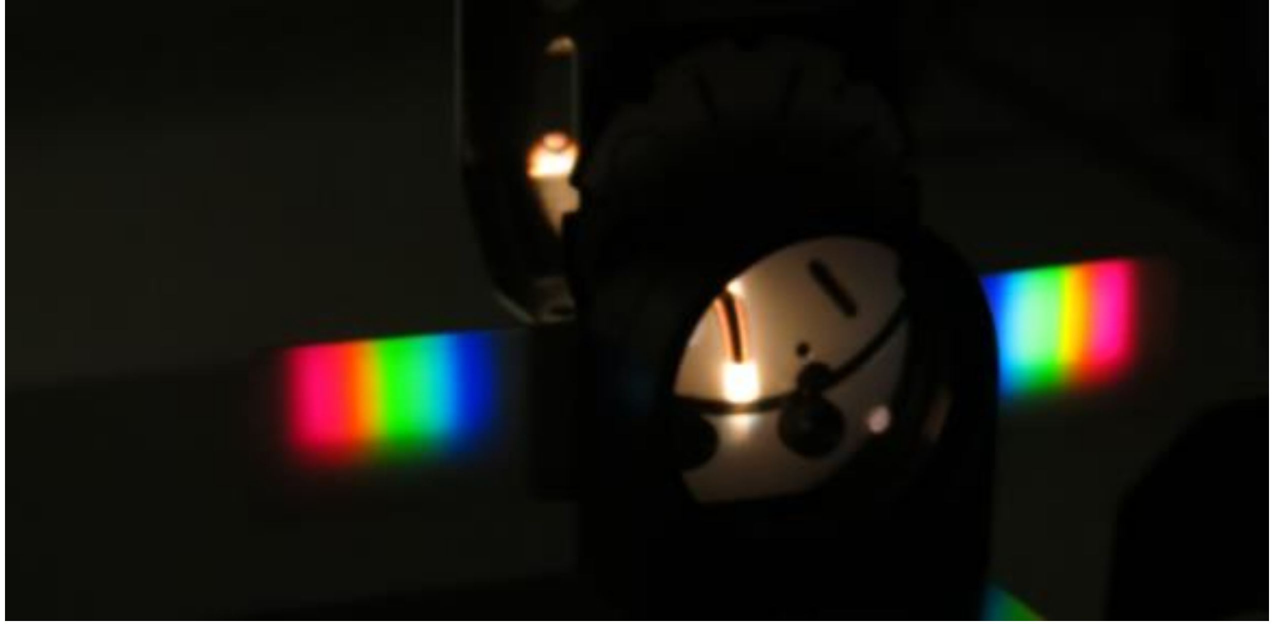
- Characterization of the Cell Phone detector in the lab:

  1- Measurement of the spectral response of the sensor

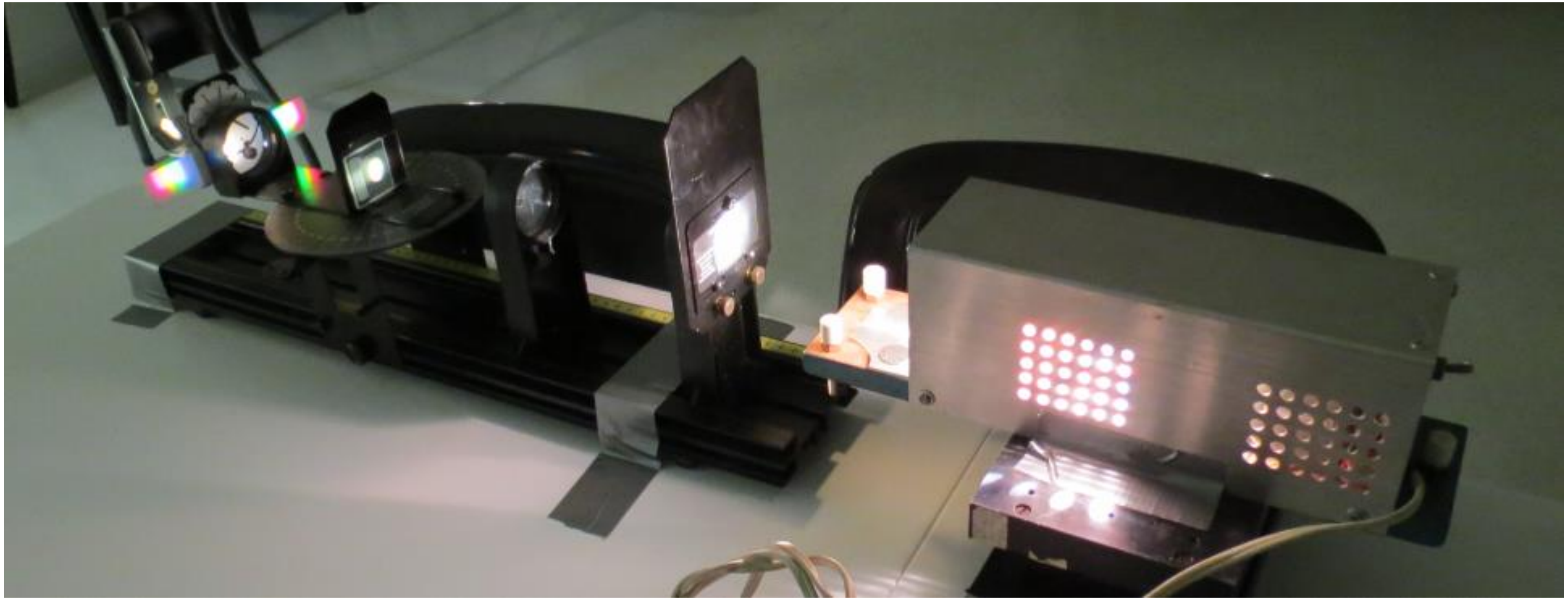
  2- Malus Law:
    - Measurement of the sensor linearity
    - Exploration of linear polarization

  3- Measurement of sun and sky radiances
    - radiance measurements with the cell phone and rotating base
    - radiance measurements with the NASA AERNET sunphotometer.

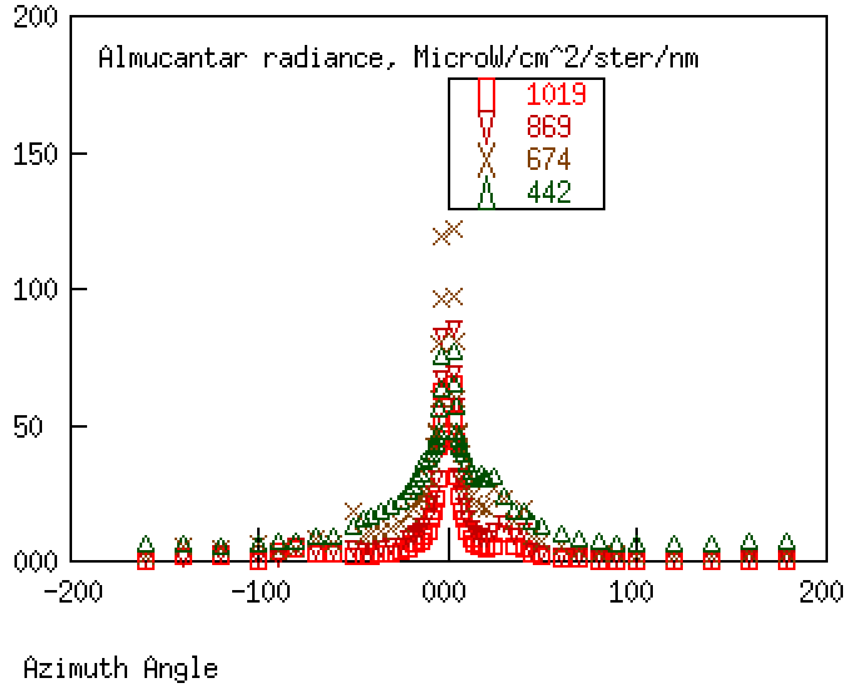
  4- Measurement of solar and sky polarization
    - Quantitative: almucantar measurements with the cell phone
    - Qualitative exploration with linear polarizers



Characterization of the Cell Phone Response Curve with a teaching spectrometer:



AERONET Almucantar and Inversions:



wave(μ)	t(measur)	t(fit)	ext(tot)	ext(fn)	ext(crs)
442	0.6048	0.6043	0.3894	0.3539	0.0355
675	0.2325	0.2329	0.1822	0.1441	0.0382
870	0.1388	0.1383	0.1248	0.0852	0.0396
1020	0.1029	0.1030	0.0960	0.0556	0.0404

Wave	RefR	RefR(min)	RefR(max)	RefI	Asymm.Fctr
0.44	1.35	1.31	1.39	0.0056	0.6926
0.68	1.36	1.33	1.40	0.0054	0.6043
0.87	1.39	1.35	1.43	0.0055	0.5717
1.02	1.38	1.35	1.43	0.0055	0.5786

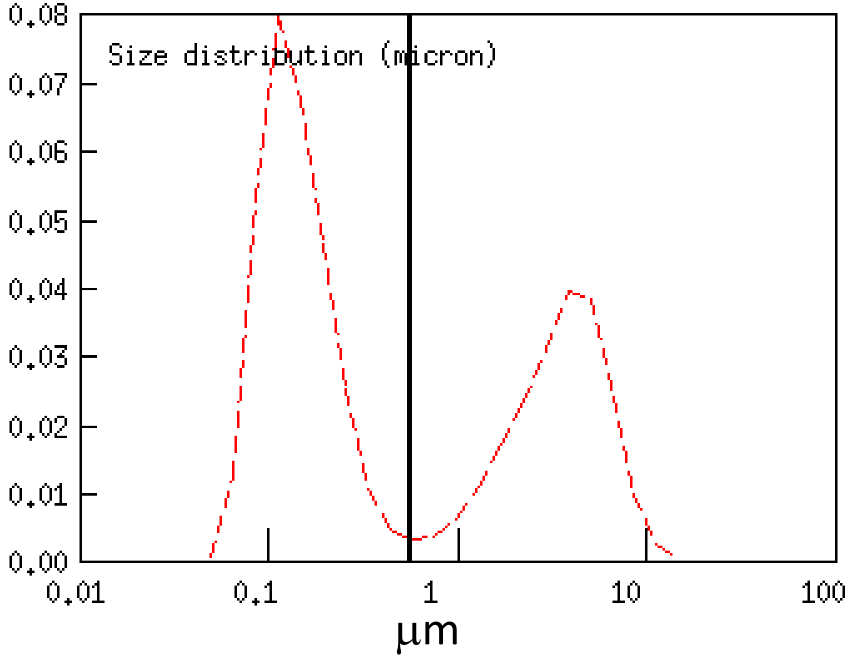
Wave	SSA(t)	SSA(min)	SSA(max)	DFlux	Albedo
0.44	0.935	0.903	0.968	559.6	0.045
0.68	0.912	0.858	0.970	449.6	0.123
0.87	0.899	0.838	0.965	290.8	0.199
1.02	0.889	0.821	0.962	213.9	0.213

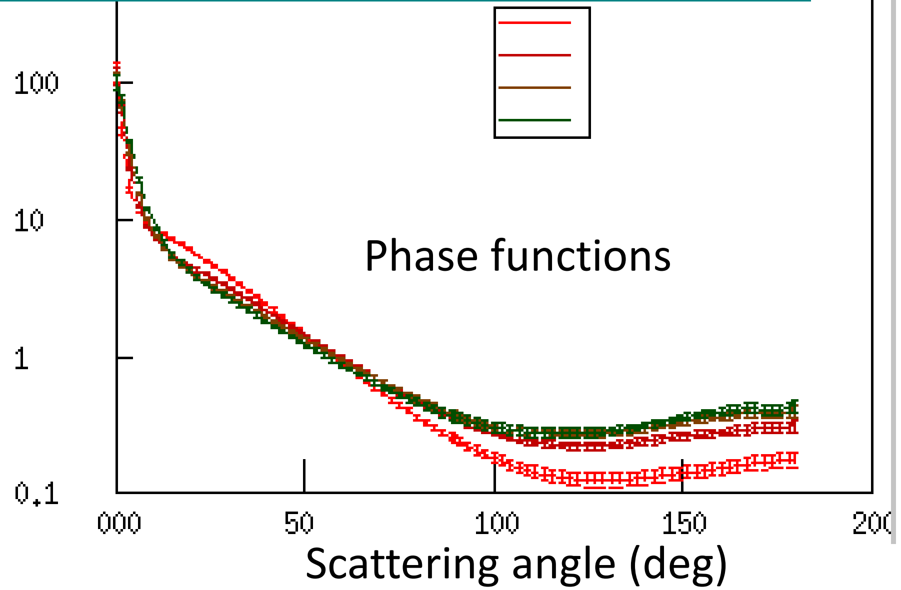
Inflection Point = 0.58

Value	Total	Fine	Coarse
Cv	0.1400	0.0820	0.0570
Reff	0.2100	0.1280	2.7260
Rv	0.5120	0.1390	3.3420
StDev	1.6450	0.4330	0.6120

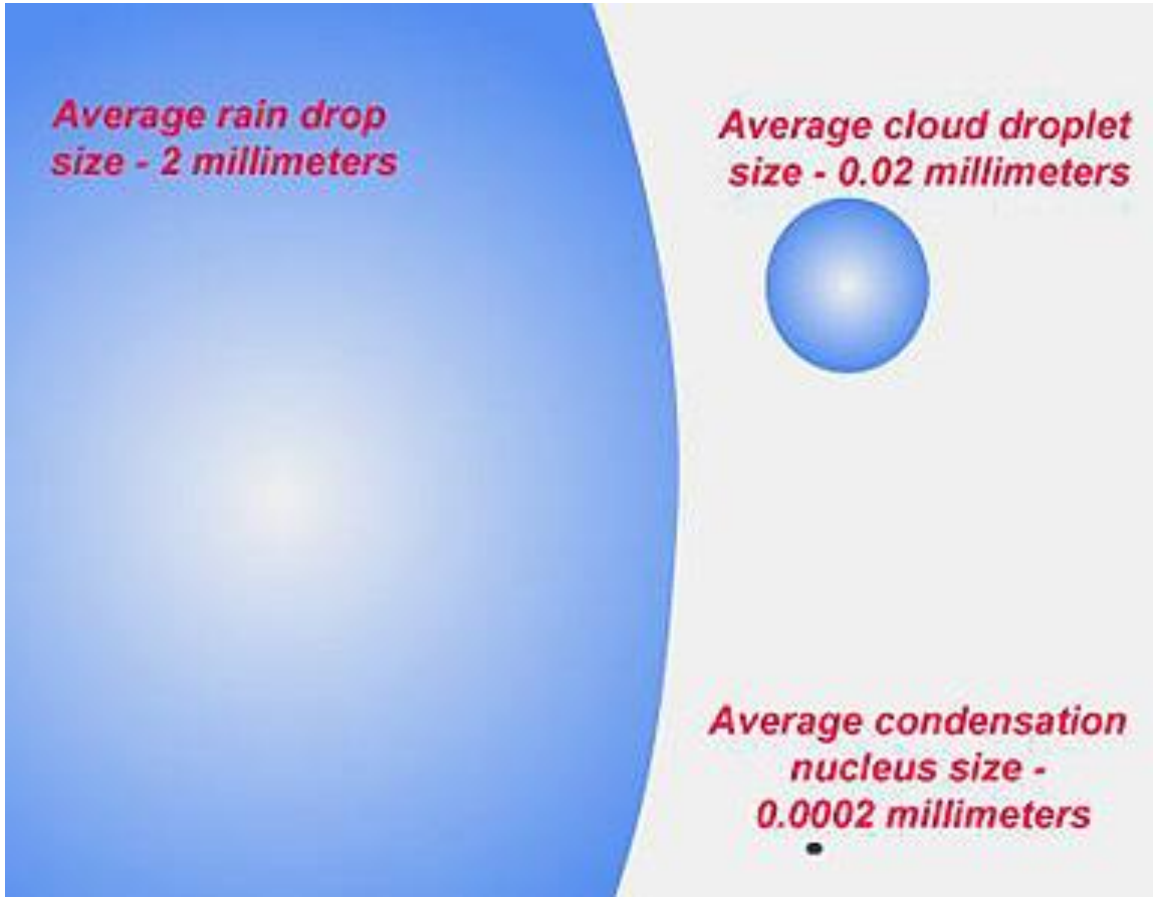
Sky Error : 3 % Sun Error : 0 % SpherPar : 98 %)

Altit	Dwnflx	Upflx	RadForc	ForcEff	SolConst
0.806	257.96	36.73	46.98	178.55	71.00
120.0	429.67	97.22	-22.26	-84.59	1319.52

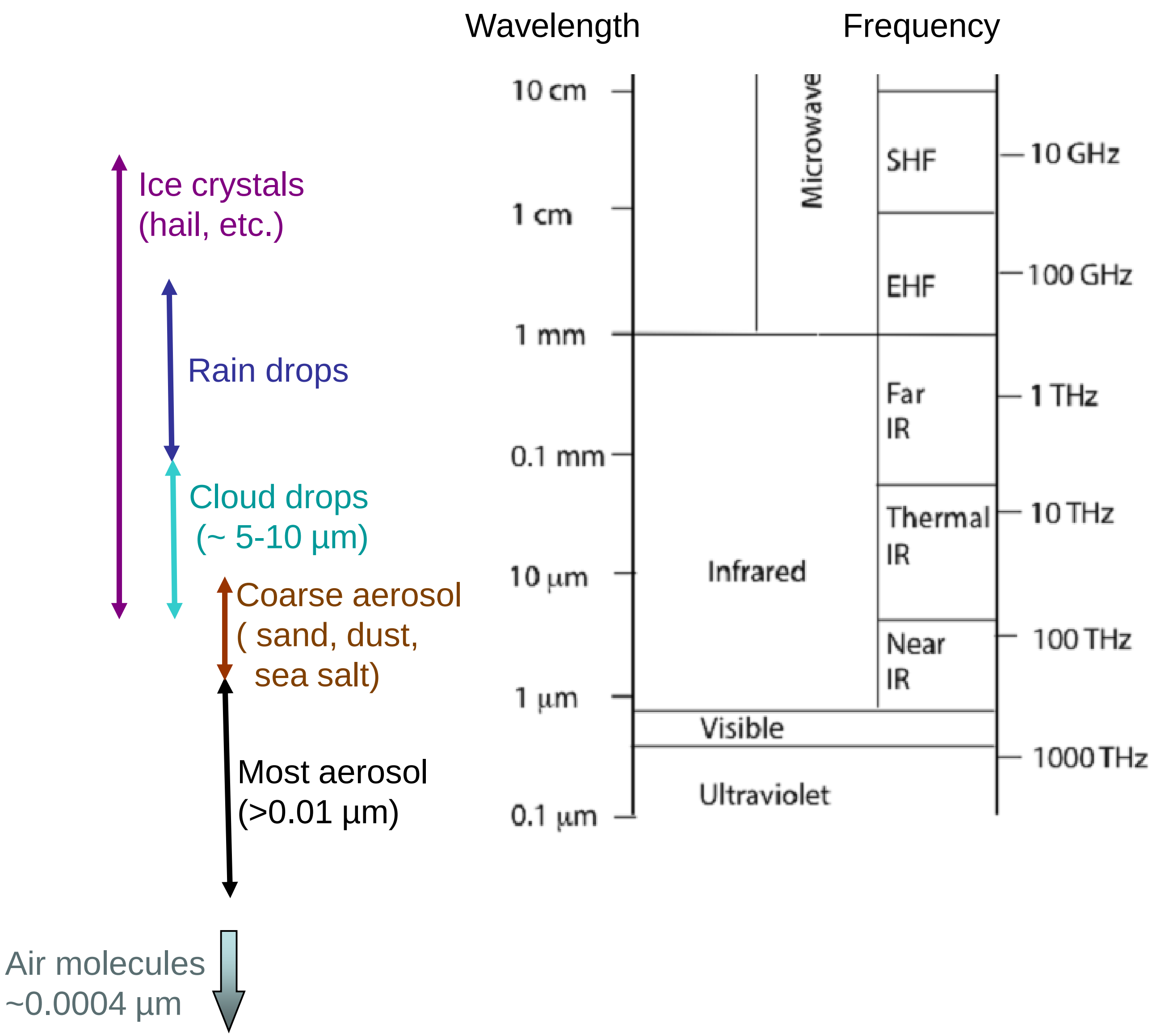




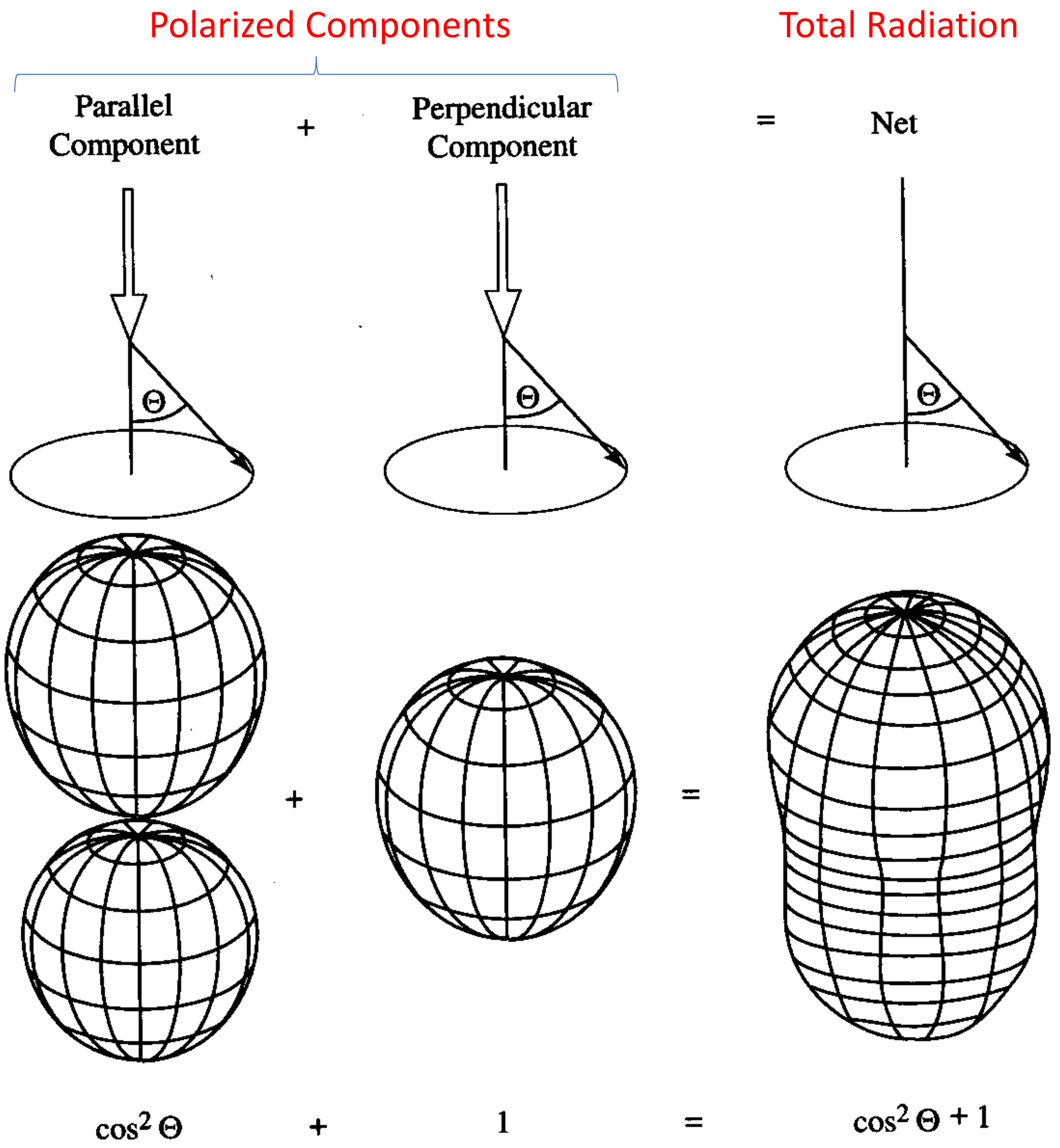
Atmospheric scatterers

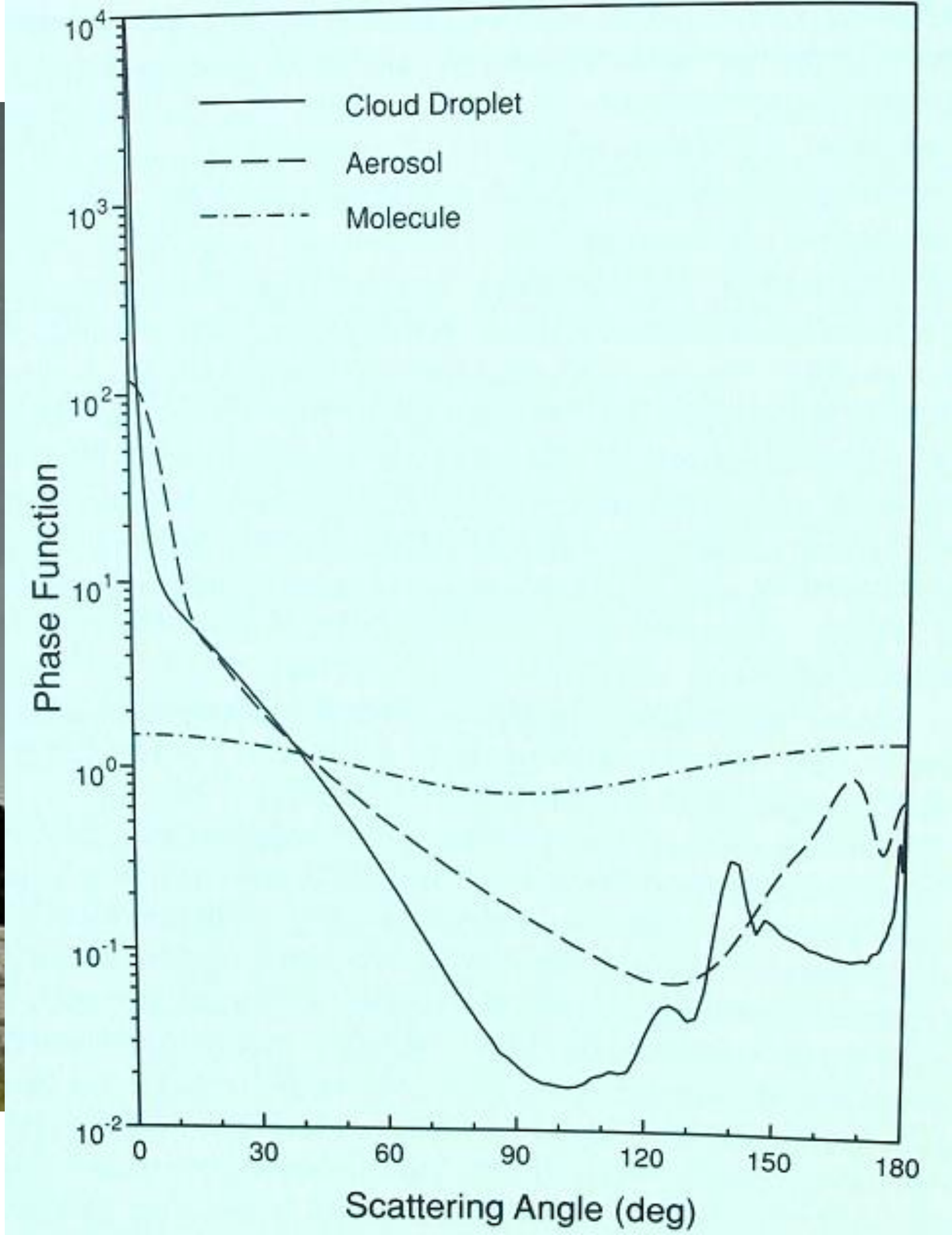


size < ≈ > wavelength



Phase Function diagram for Rayleigh scattering





Cloud Droplet
Aerosol
Molecule
Phase Function
Scattering Angle (deg)
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
0
30
60
90
120
150
180

Information from Polarization

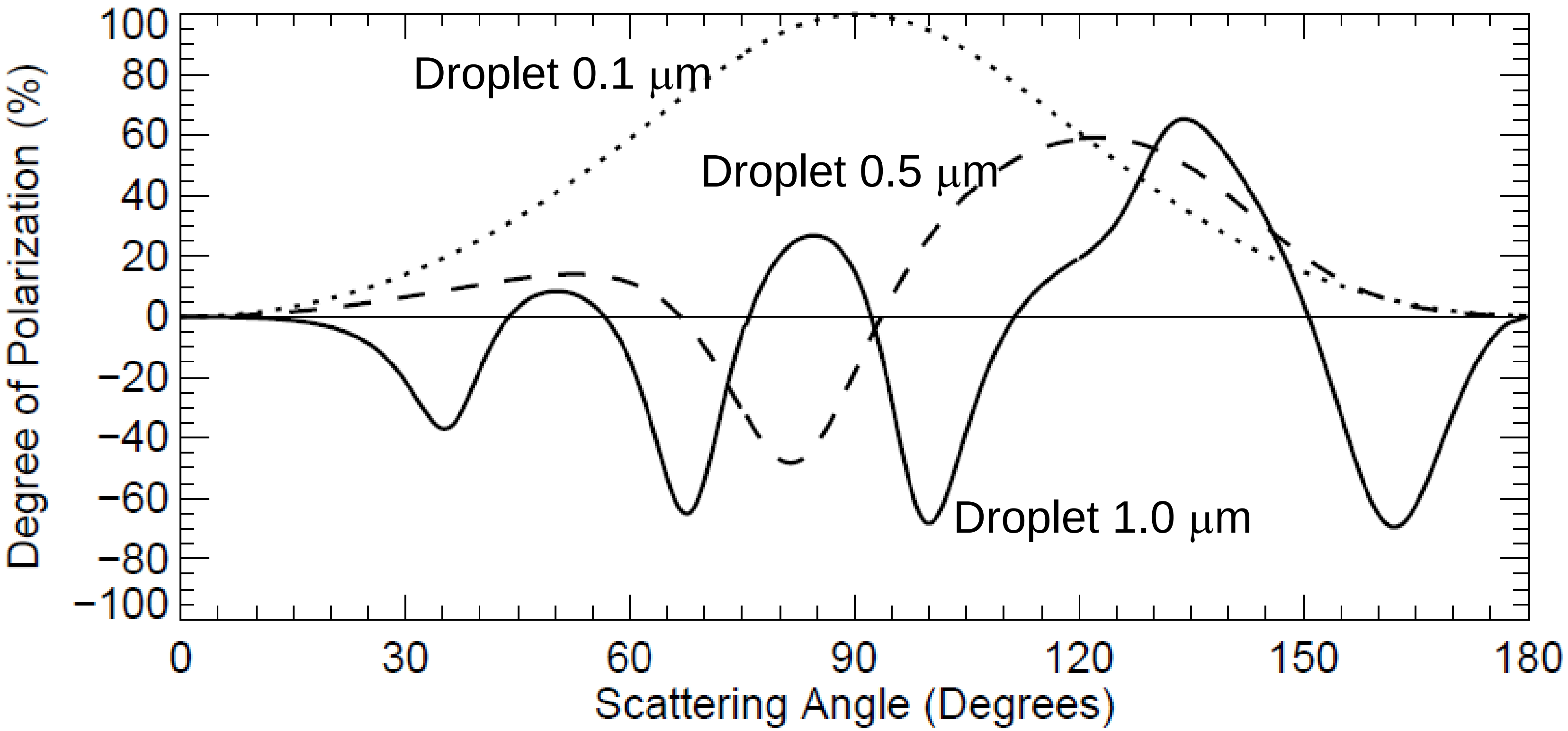
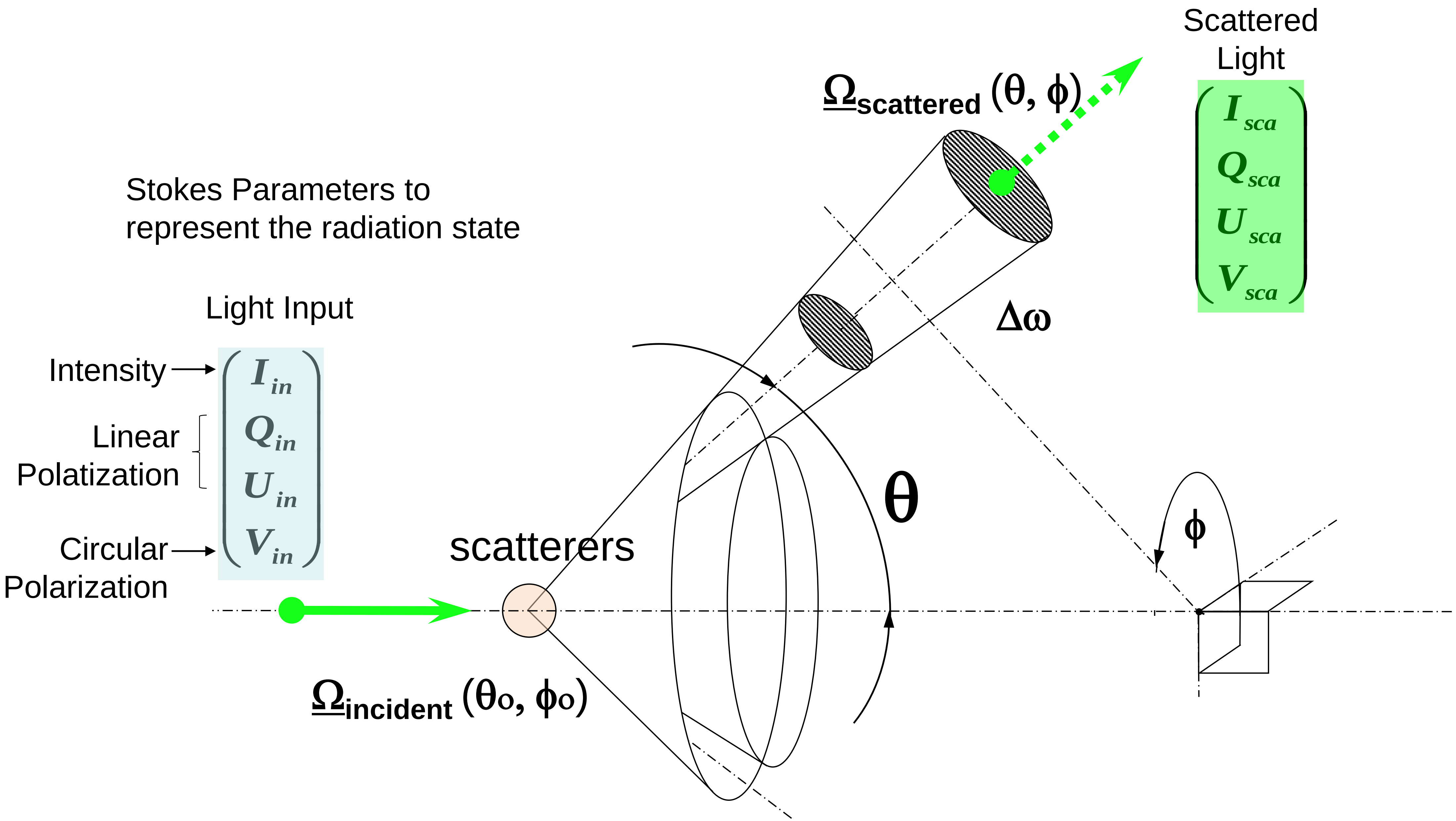
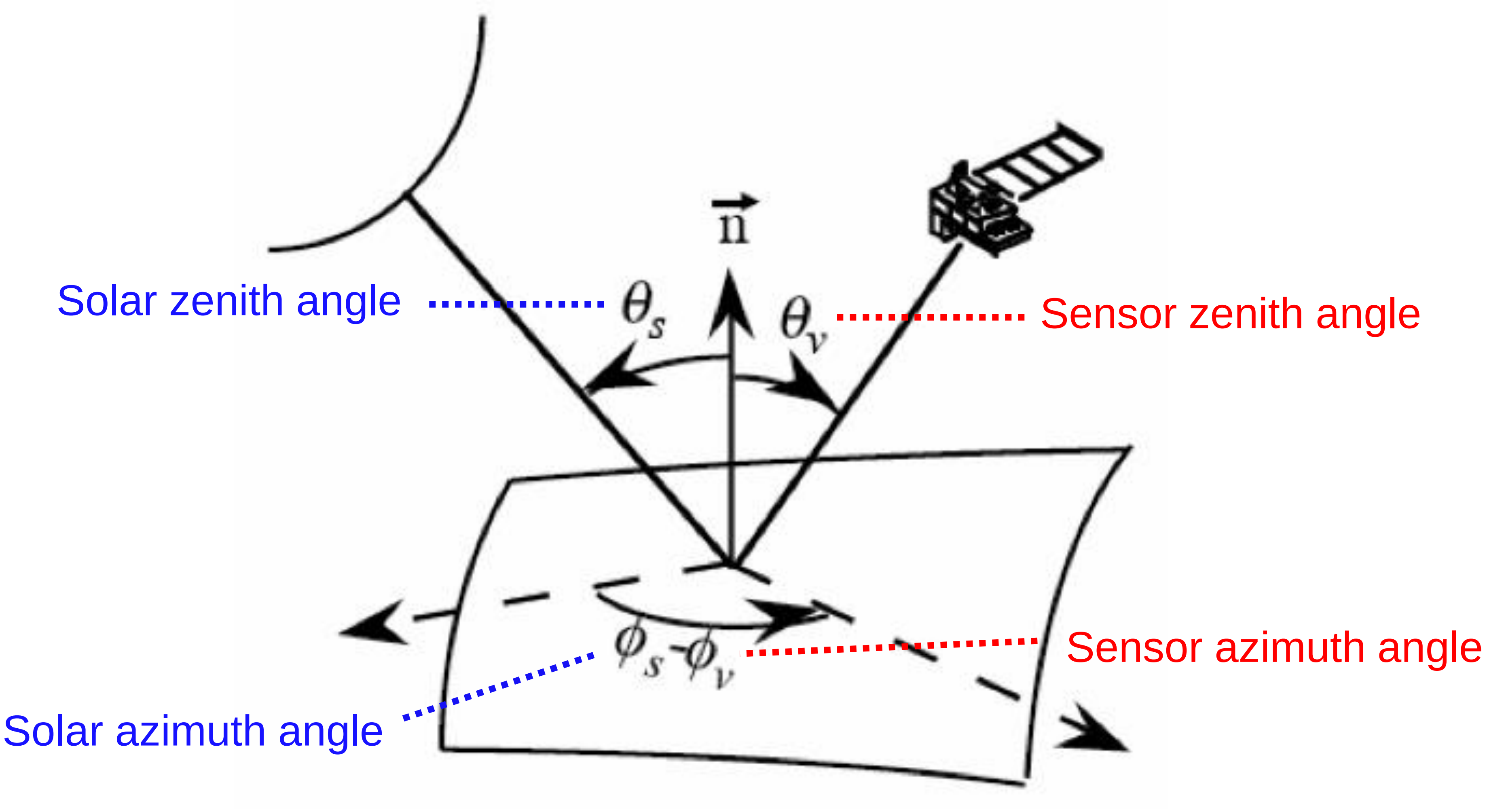


Figure 7.12: Degree of polarization of light scattered by water droplets of different size. The dotted curve is for a droplet of diameter 0.1 μm, the dashed curve for 0.5 μm, the solid curve for 1.0 μm; $\lambda = 0.55$ μm and $n = 1.33$. The incident light is unpolarized.


Stokes Parameters to
represent the radiation state
Light Input
Intensity
Linear
Polatization
Circular
Polarization
I_{in}
Q_{in}
U_{in}
V_{in}
scatterers
$\Omega_{incident}$ (θ_o, ϕ_o)
$\Omega_{scattered}$ (θ, ϕ)
Scattered
Light
I_{sca}
Q_{sca}
U_{sca}
V_{sca}
$\Delta\omega$
θ
ϕ

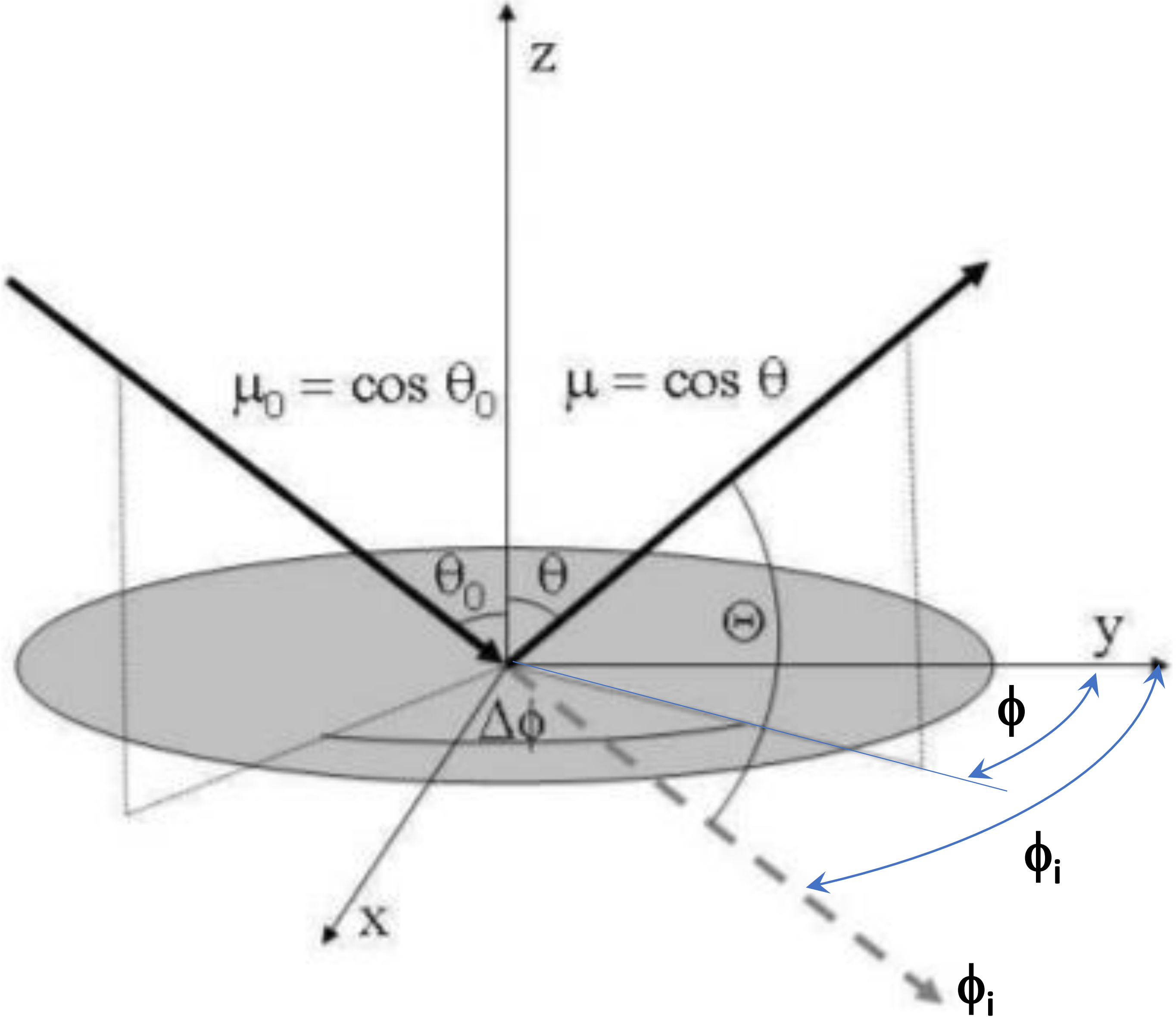
Observing geometry from Space:



Solar zenith angle θ_o
Solar azimuth angle: ϕ_o
Sensor zenith angle: θ
Sensor azimuth angle: ϕ

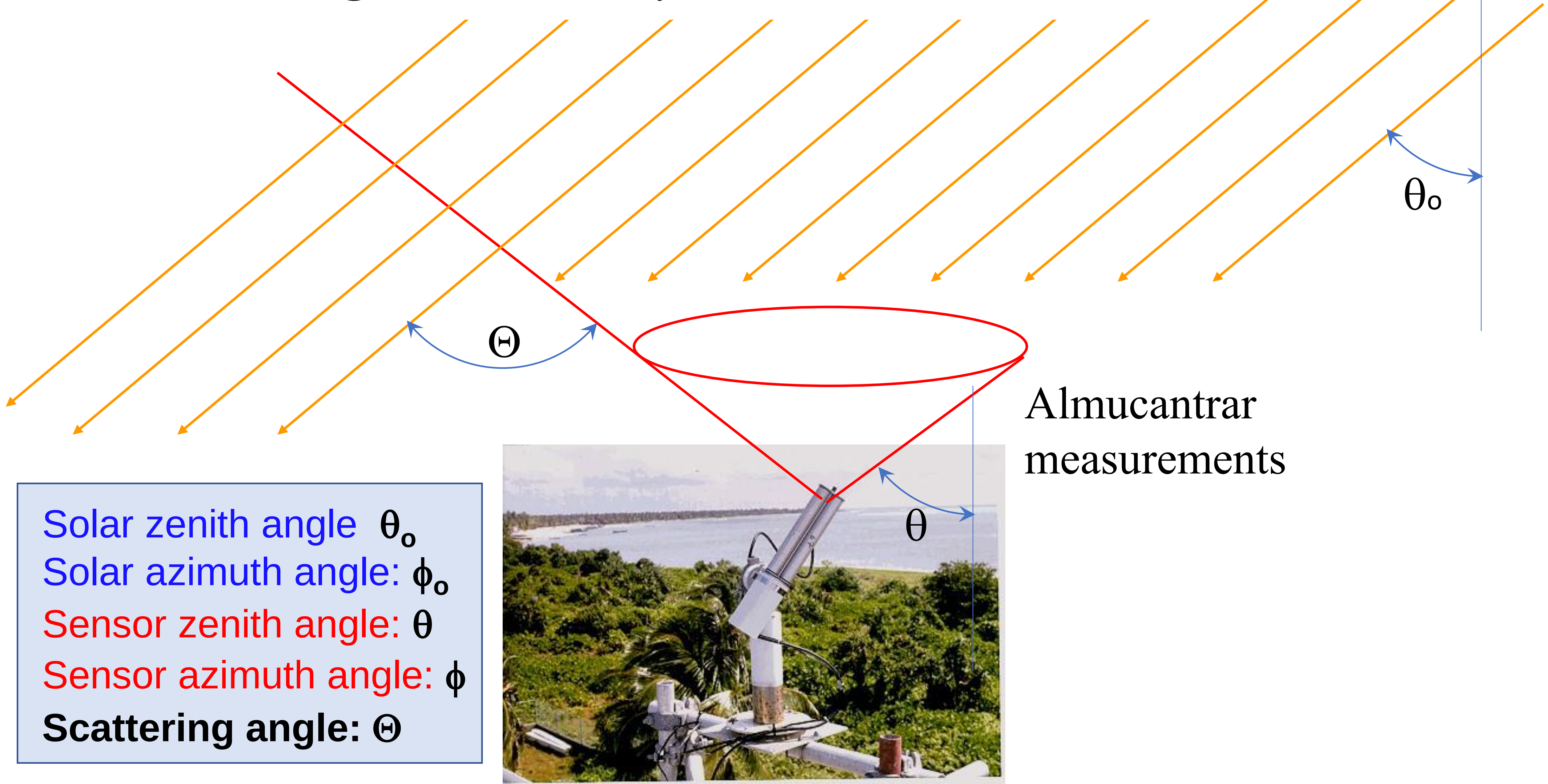
Scattering angle: Θ

Reference: R. G. Grainger
An Atmospheric Radiative Transfer Pimer



$$\cos\Theta = \sin\theta_i \cos\phi_i \sin\theta_i \cos\phi_i + \sin\theta_i \sin\phi_i \sin\theta \sin\phi + \cos\theta_i \cos\theta$$
$$= \cos\theta_i \cos\theta + \sin\theta_i \sin\theta \cos(\phi_i - \phi)$$

Scattering Geometry from the Ground



Solar zenith angle θ_o

Solar azimuth angle: ϕ_o

Sensor zenith angle: θ

Sensor azimuth angle: ϕ

Scattering angle: Θ

GODDARD SPACE FLIGHT CENTER

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https://youtu.be/i_CJW3JsBI4

+ AEROSOL OPTICAL DEPTH | + AEROSOL INVERSIONS | + SOLAR FLUX | + OCEAN COLOR | + MARITIME AEROSOL

Web Site Feature AERONET Data Synergy Tool - **Access Earth Science data sets for AERONET sites**

-Home

Home

+ AEROSOL/FLUX NETWORKS
+ CAMPAIGNS
+ COLLABORATORS
+ DATA
+ LOGISTICS
+ NASA PROJECTS
+ OPERATIONS
+ PUBLICATIONS
+ SITE INFORMATION
+ STAFF
+ SYSTEM DESCRIPTION

AERONET DATA ACCESS

DATA SYNERGY TOOL

Recent Product Releases (navigation links also available above and in left margin):

8 February 2019:
Version 3 Inversion Uncertainty Estimates for Selected Products - Estimated Uncertainty Description - Download Tool

Version 3 Lunar AOD Measurements (Provisional) - Web Display

15 October 2018:
Version 3 Level 1.5 and Level 2.0 Hybrid inversion products - Hybrid Description - Web Display

11 January 2018:
Version 3 Level 1.5 and Level 2.0 Almucntar inversion products - Almucantar Description - Web Display

5 January 2018:
Version 3 Level 2.0 AOD and SDA products - AOD and SDA Description - Web Display

MISSION

The AERONET (**AE**rosol **RO**botic **NET**work) project is a federation of ground-based remote sensing aerosol networks established by **NASA** and **PHOTONS** (PHOtométrie pour le Traitement Opérationnel de Normalisation Satellitaire; **Univ. of Lille 1**, **CNES**, and **CNRS-INSU**) and is greatly expanded by networks (e.g., **RIMA**, **AeroSpan**, **AEROCAN**, and CARSNET) and **collaborators** from national agencies, institutes, universities, individual scientists, and partners. For more than 25 years, the project has provided long-term, continuous and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases. The network imposes standardization of **instruments**, **calibration**, **processing** and **distribution**.

AERONET collaboration provides globally distributed observations of spectral aerosol optical depth (AOD), inversion products, and precipitable water in diverse aerosol regimes. Version 3 AOD data are computed for three data quality levels: Level 1.0 (unscreened), Level 1.5 (cloud-screened and quality controlled), and Level 2.0 (quality-assured). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality checks.

Retrieval scheme:

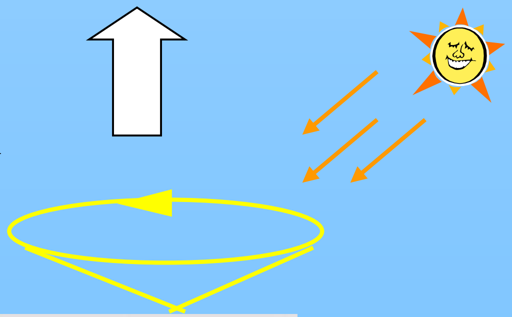
Forward model:
-Spectral and angular scattering by particles with different sizes, compositions and shapes
- Accounting for multiple scattering in atmosphere

(Dubovik and King, JGR, 2000)

Observations

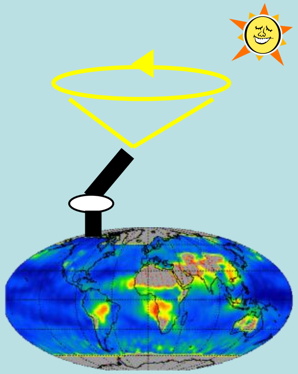
Numerical inversion:
-Accounting for noise
-Solving Ill-posed problem
- Setting a priori constraints

- Direct solar
- Almucantar
- Principal Plane Scan

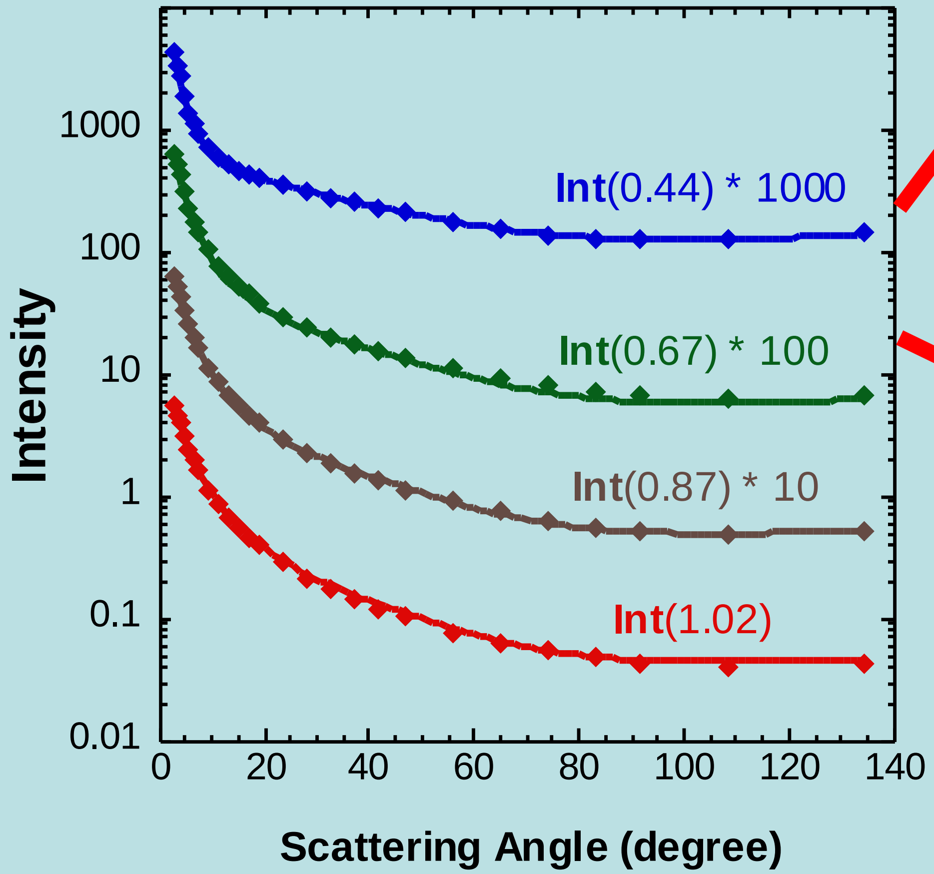


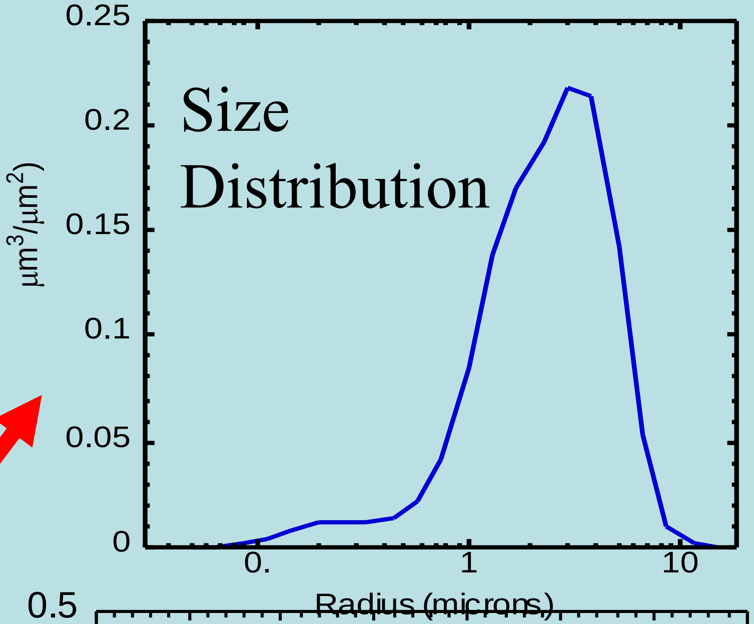
aerosol particle sizes,
refractive index,
single scattering albedo, etc.

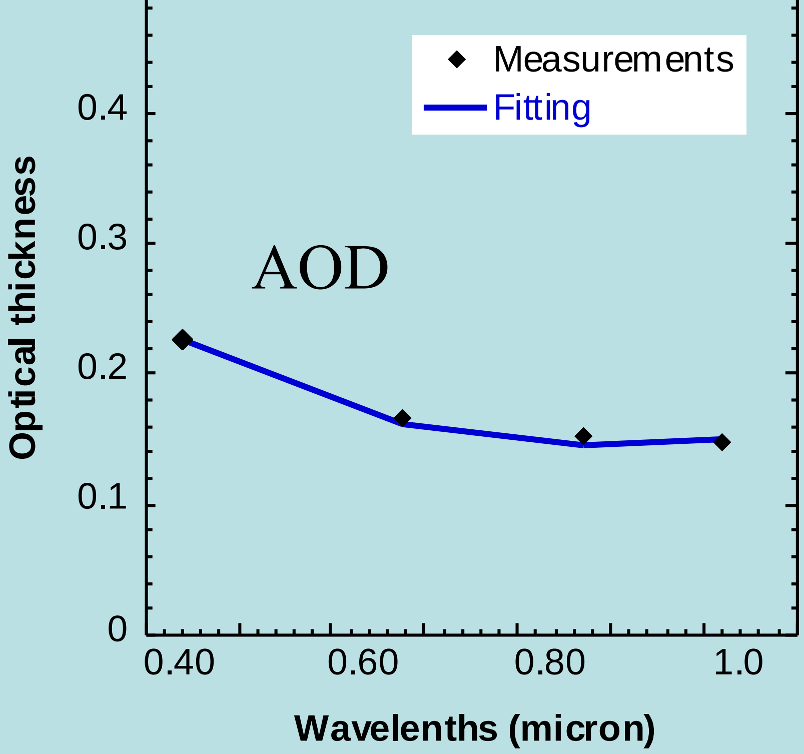
Fitting as a retrieval strategy



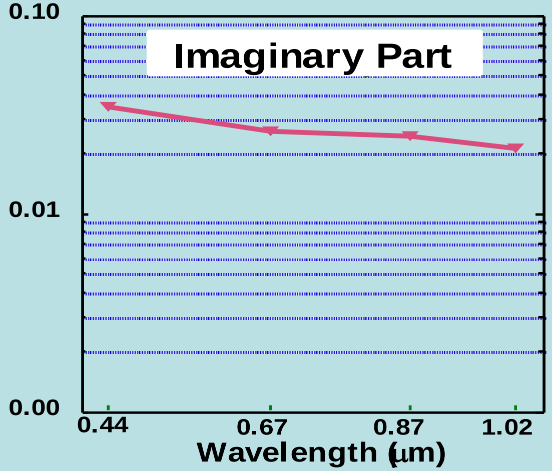
Almucantar Fitting

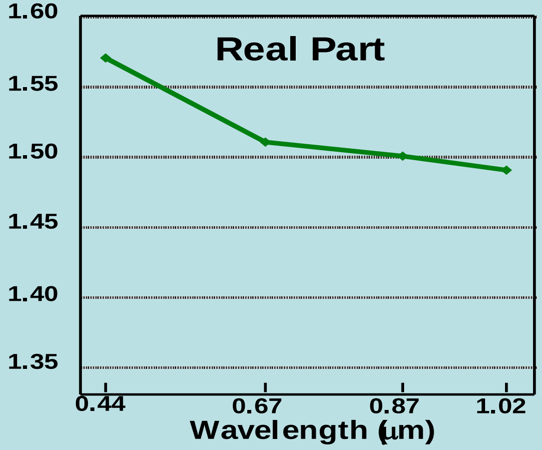






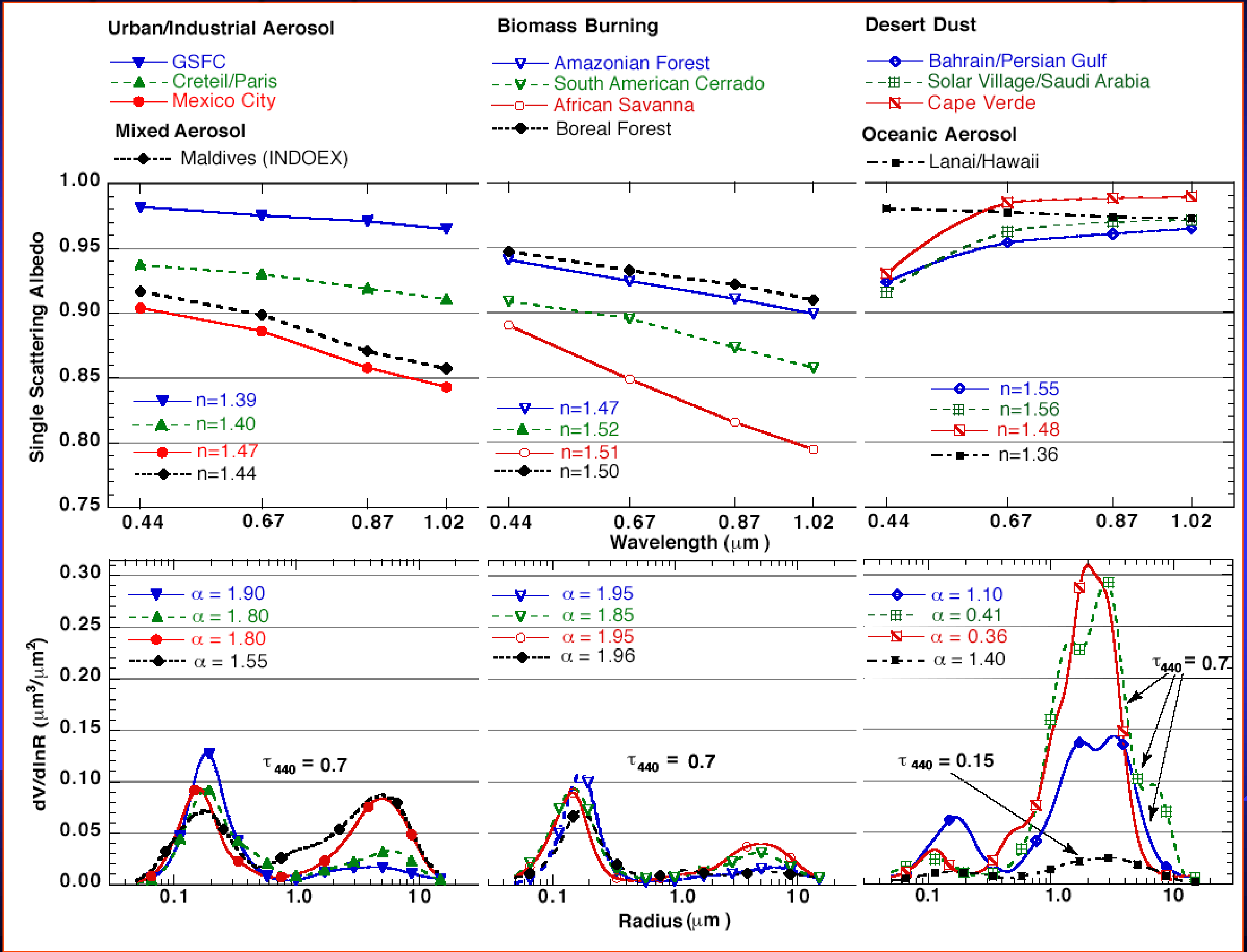
Refractive Indices





The averaged optical properties of various aerosol types

(Dubovik et al., 2002, JAS)

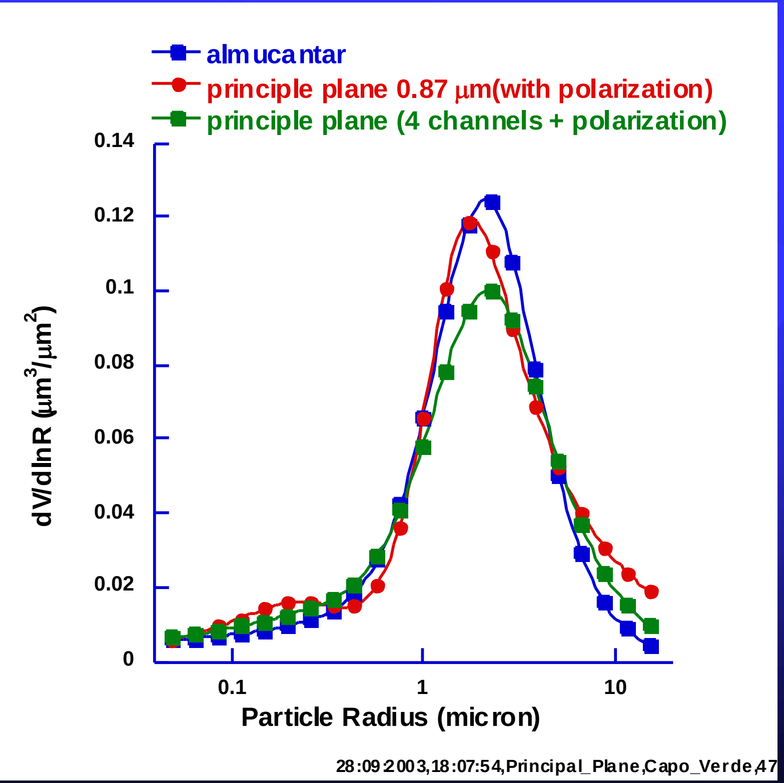


Utilizing polarization *Cape Verde aerosol*

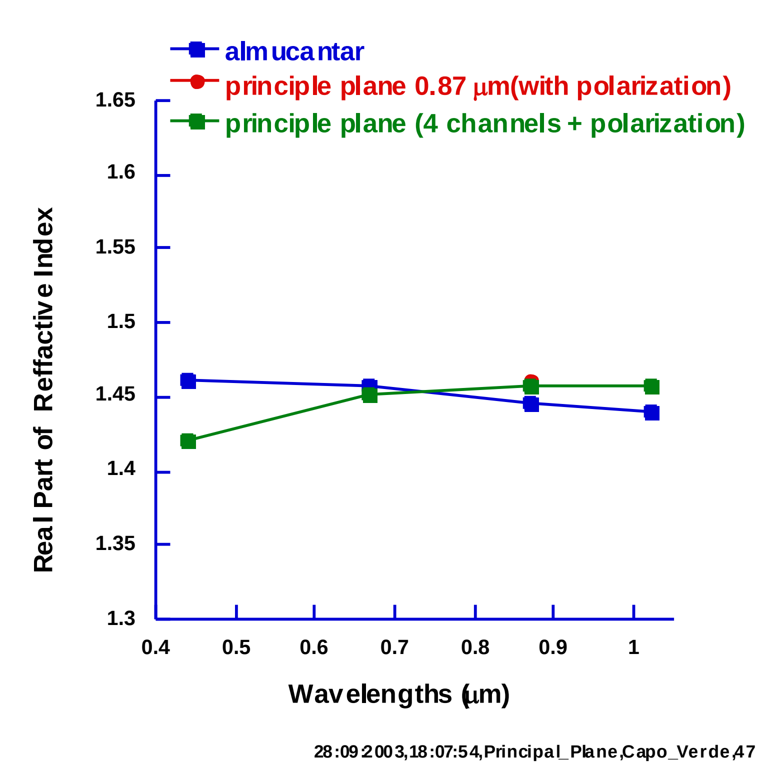
Principal Plane:
$\tau(\lambda)$, $I(\lambda,\Theta)$
λ = 0.44, 0.5, 0.67, 0.87,1.02, 1.64, μm

Polarization :
$\tau(\lambda)$, $I(\lambda,\Theta)$,$P(\lambda,\Theta)$
λ = 0.87μm

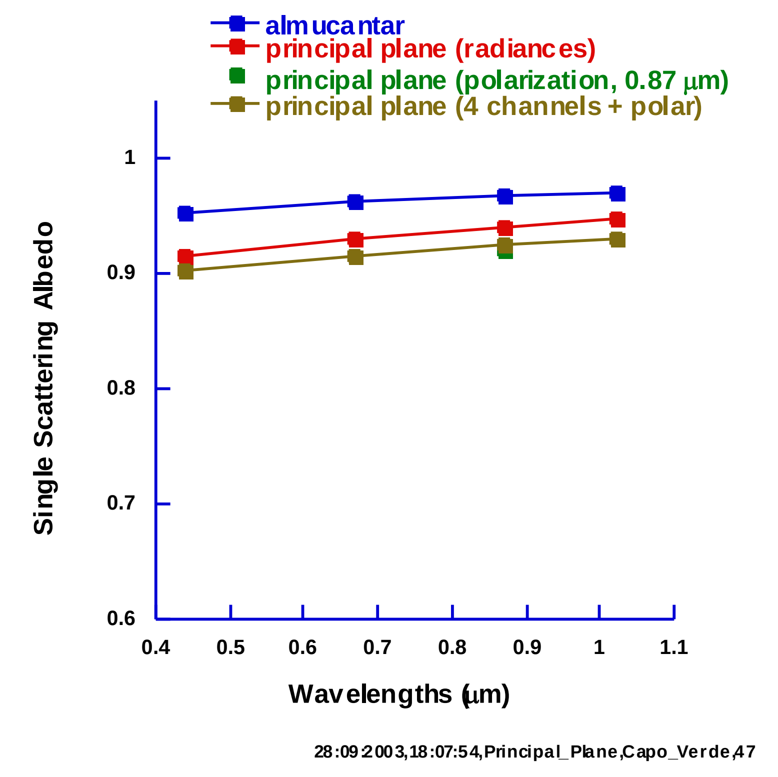
$dV/d\ln(r_i)$



$n(\lambda)$



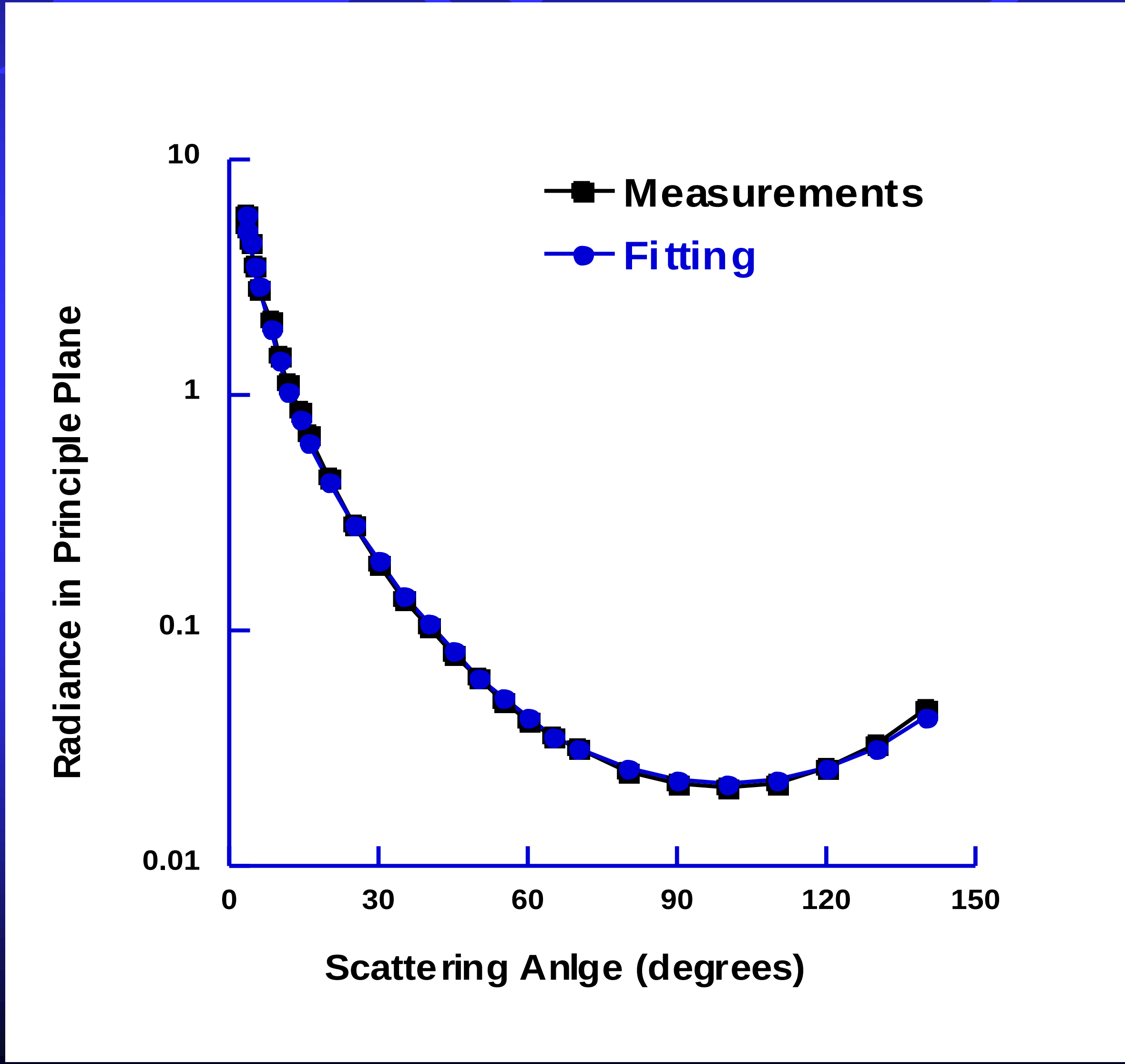
$\omega_0(\lambda)$



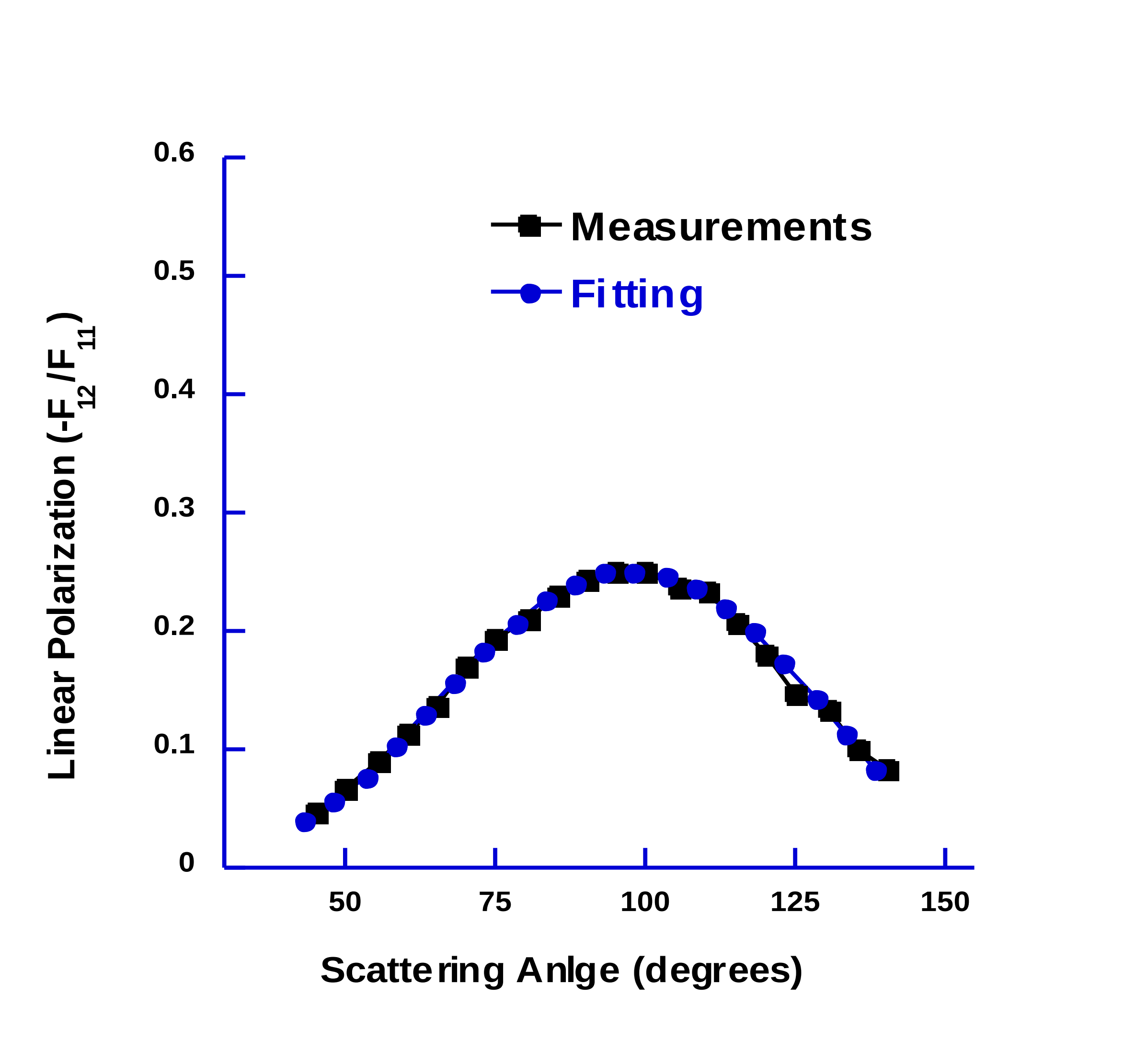
Cape Verde aerosol

Fitting polarization

Radiance

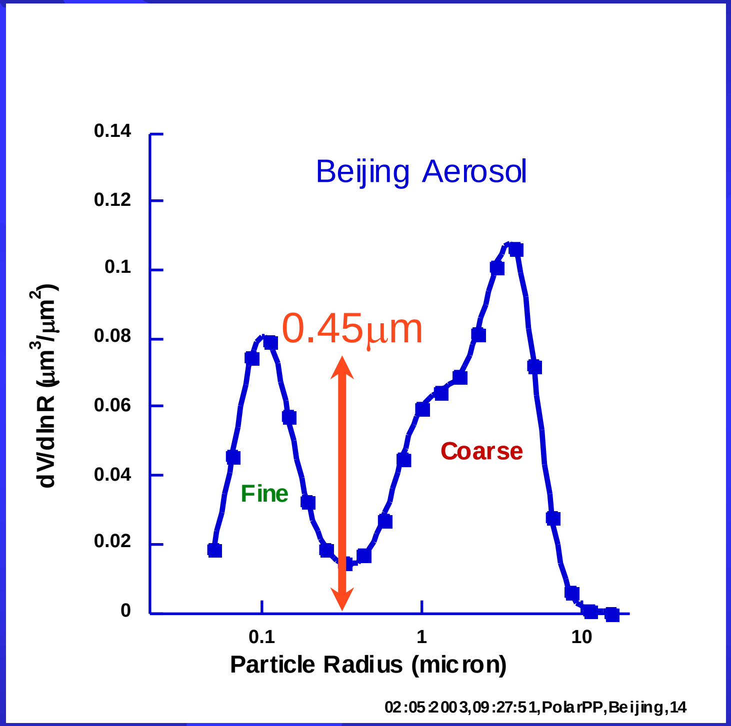


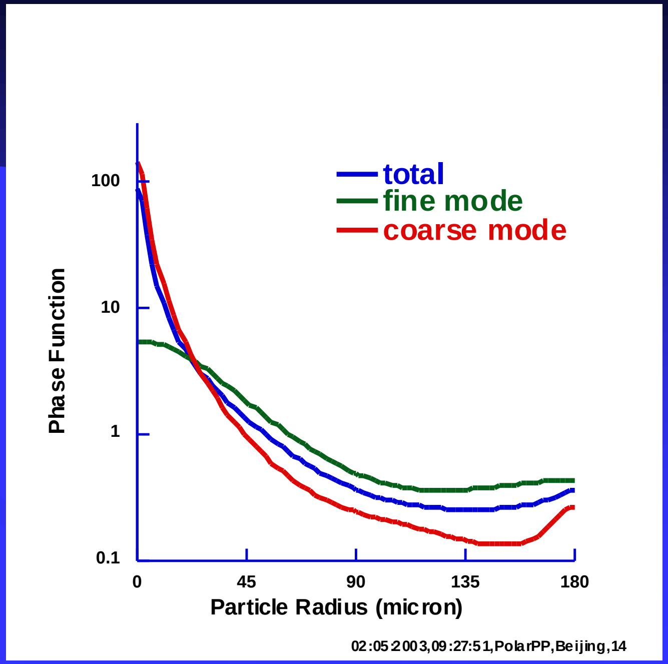
Linear Polarizartion

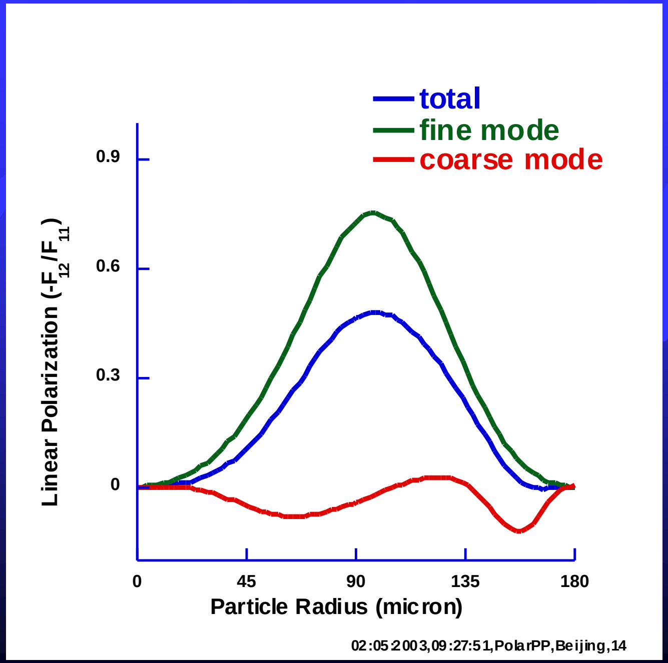


Fine and Coarse modes separations

Beijing aerosol

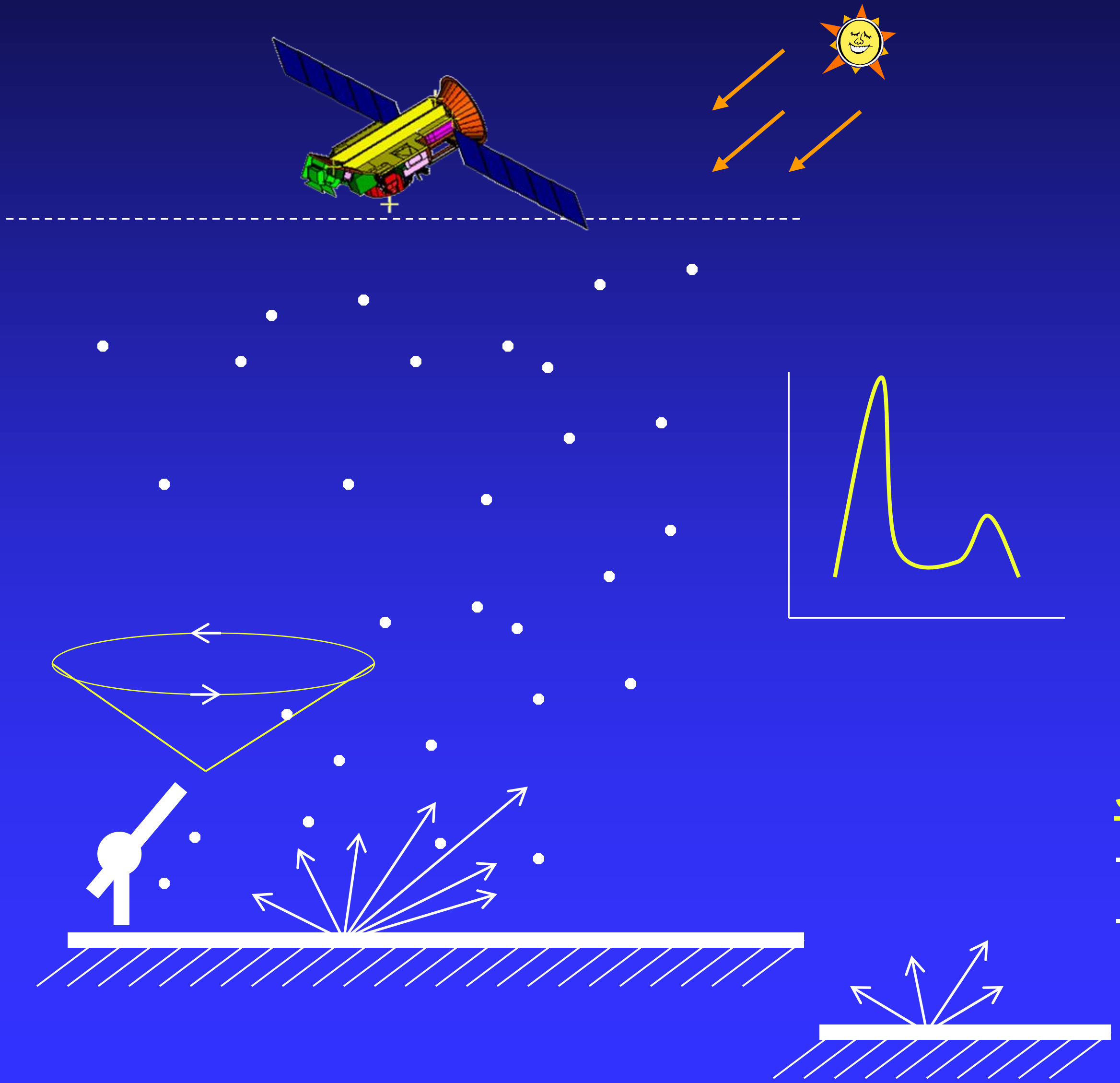






Flexible separation between fine and coarse modes (curently: ~0.6 μm)

Retrieval using combinations of up-looking Ground-based and down-looking satellite observations



Retrieved:

Aerosol Properties:

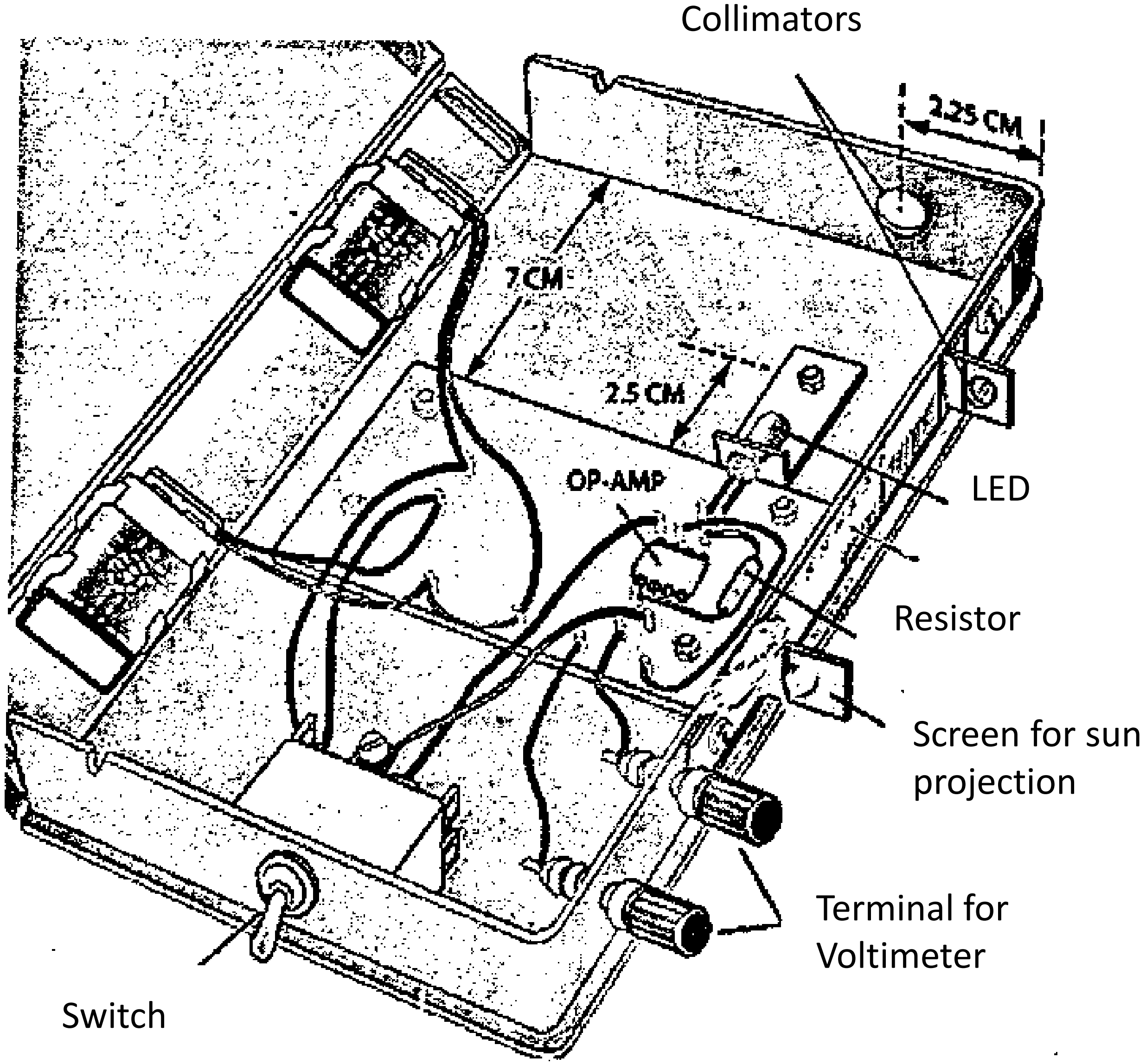
- size distribution
- real ref. ind.
- imag. ref. ind
(AERONET sky channels)

Surface Parameters:

-BRDF (MISR channels)
-Albedo (MODIS IR channels)

Non-Expensive LED Sun-Photometer

Example of Mechanical Assembly:
(extracted from F. Mims III, Scientific American)



Very Inexpensive Project done inside a box of a video Cassete Tape

Quantitative calibration of a sunphotometer using Langley plots.

Sun photometer with light-emitting diodes as spectrally selective detectors

Forrest M. Mims III

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Received 21 February 1992.
0003-6935/92/336965-03$05.00/0.

20 November 1992 / Vol. 31, No. 33 / APPLIED OPTICS 6965

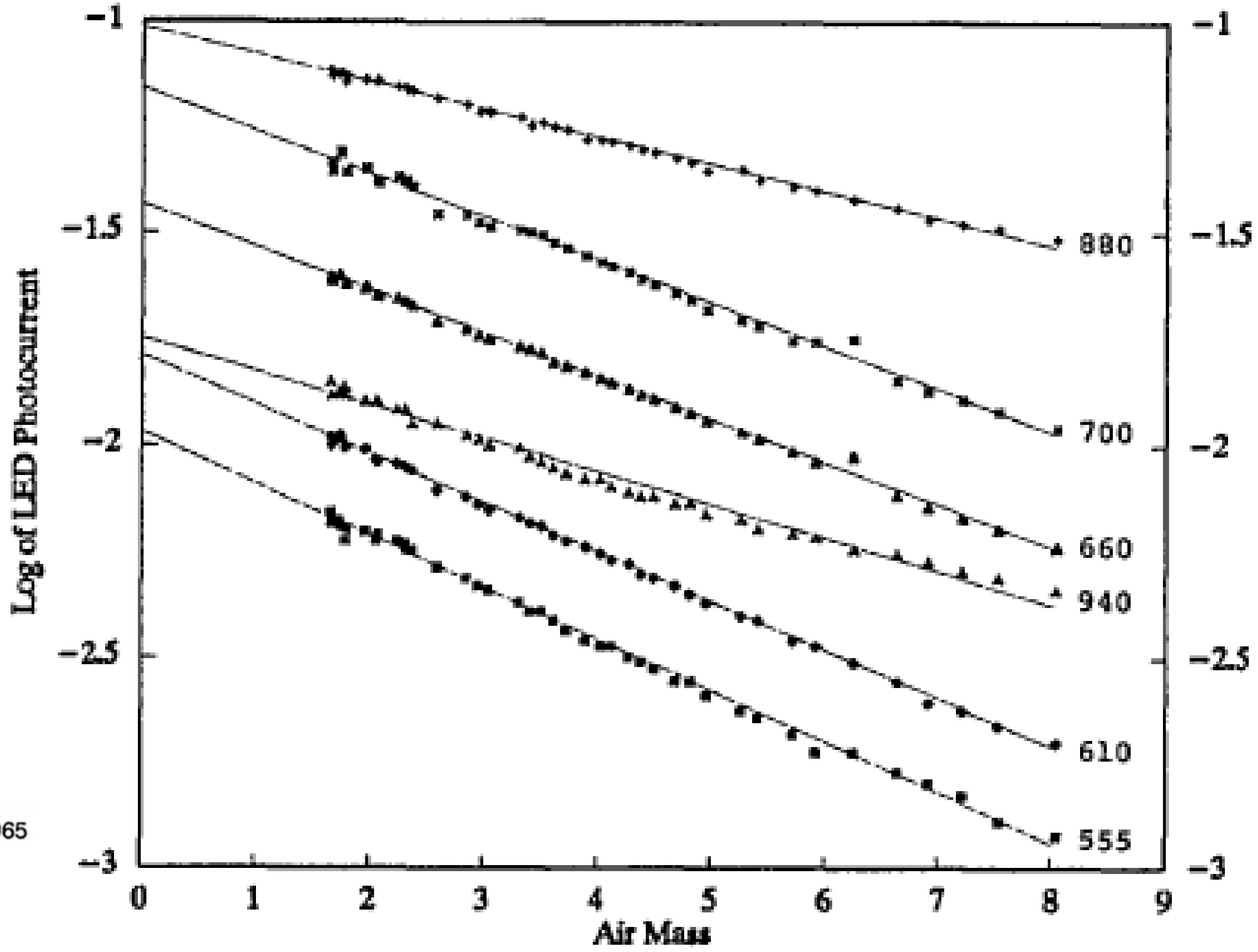


Fig. 2. Langley plot for each channel of a LED sun photometer.

Use of an inexpensive sunphotonmeter for aerosol measurements:

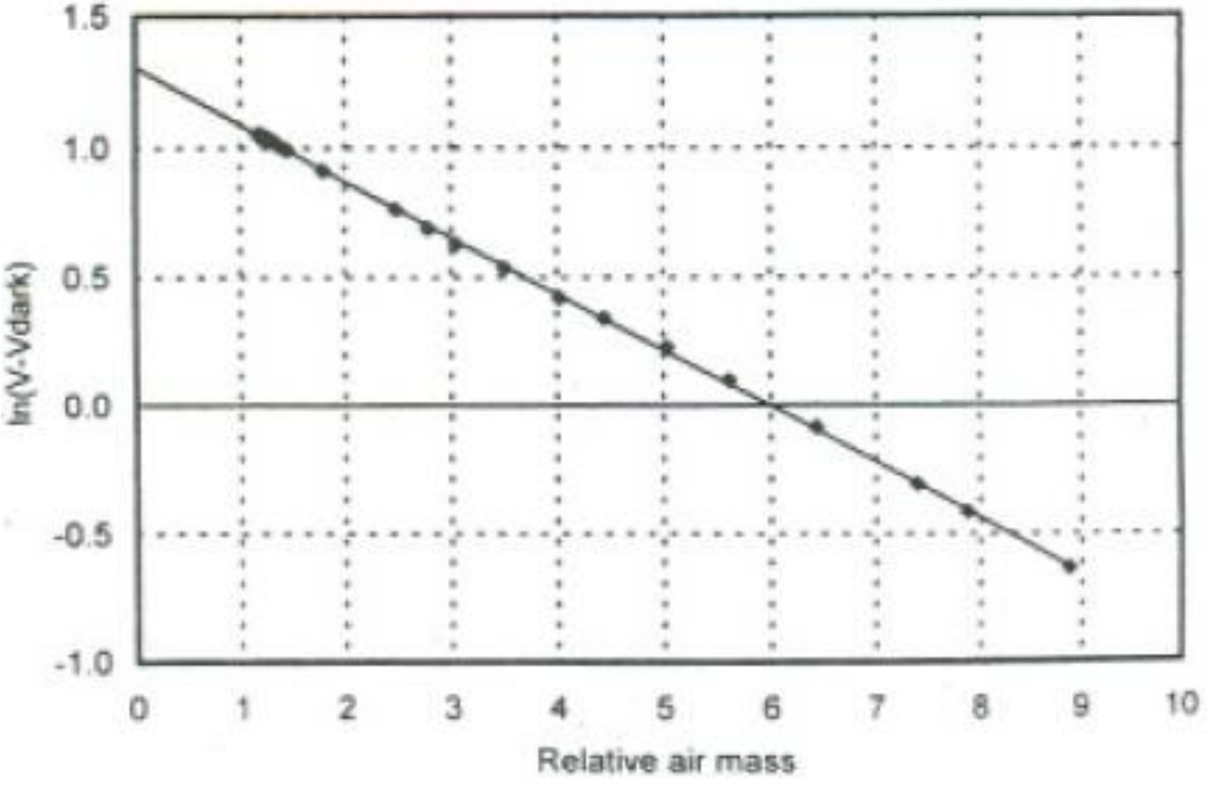


Figure 1. Langley plot calibration for a light-emitting diode (LED) based Sun photometer, from Seguin, Texas, March 9, 1999 (unpublished data from Mims).

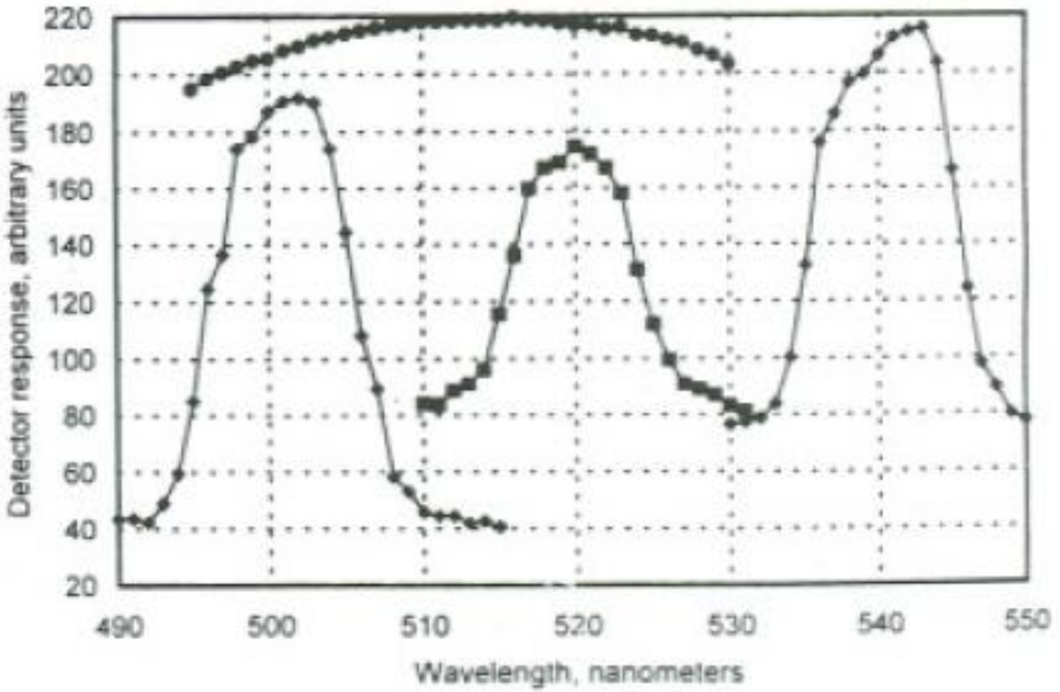


Figure 4. Spectral response for detectors in a modified MicroTops Sun photometer. The detector marked by crosses is the Agilent HLMP-D600 emerald green LED used in the GLOBE Sun photoeter. The others are 10-nm or 80-nm filters.

References:

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 106, NO. D5, PAGES 4733–4740, MARCH 16, 2001

Development of an inexpensive handheld LED-based Sun photometer for the GLOBE program

David R. Brooks
Department of Mathematics and Computer Science, Drexel University, Philadelphia, Pennsylvania

Forrest M. Mims III
Sun Photometer Atmospheric Network, Seguin, Texas

INEXPENSIVE SUN PHOTOMETERS FOR MONITORING THE ATMOSPHERE

David R. Brooks, PhD

Research Professor, Department of Mechanical Engineering and Mechanics
Drexel University

A first-order approximation for air mass is given by

$$AM \approx \frac{1}{\cos z} \qquad (A.1)$$

where z is the zenith angle in degrees.

The above approximation overlooks the atmosphere's finite height, and predicts an infinite air mass at the horizon. However, it is reasonably accurate for values of z up to around 75°. A number of refinements have been proposed to more accurately model the path thickness towards the horizon, such as that proposed by Kasten and Young (1989):[5]

$$AM = \frac{1}{\cos z + 0.50572\,(96.07995 - z)^{-1.6364}} \qquad (A.2)$$

A more comprehensive list of such models is provided in the main article Airmass, for various atmospheric models and experimental data sets. At sea level the air mass towards the horizon (z = 90°) is approximately 38.[6]

Modelling the atmosphere as a simple spherical shell provides a reasonable approximation:[7]

$$AM = \sqrt{(r\cos z)^2 + 2r + 1} - r\cos z$$

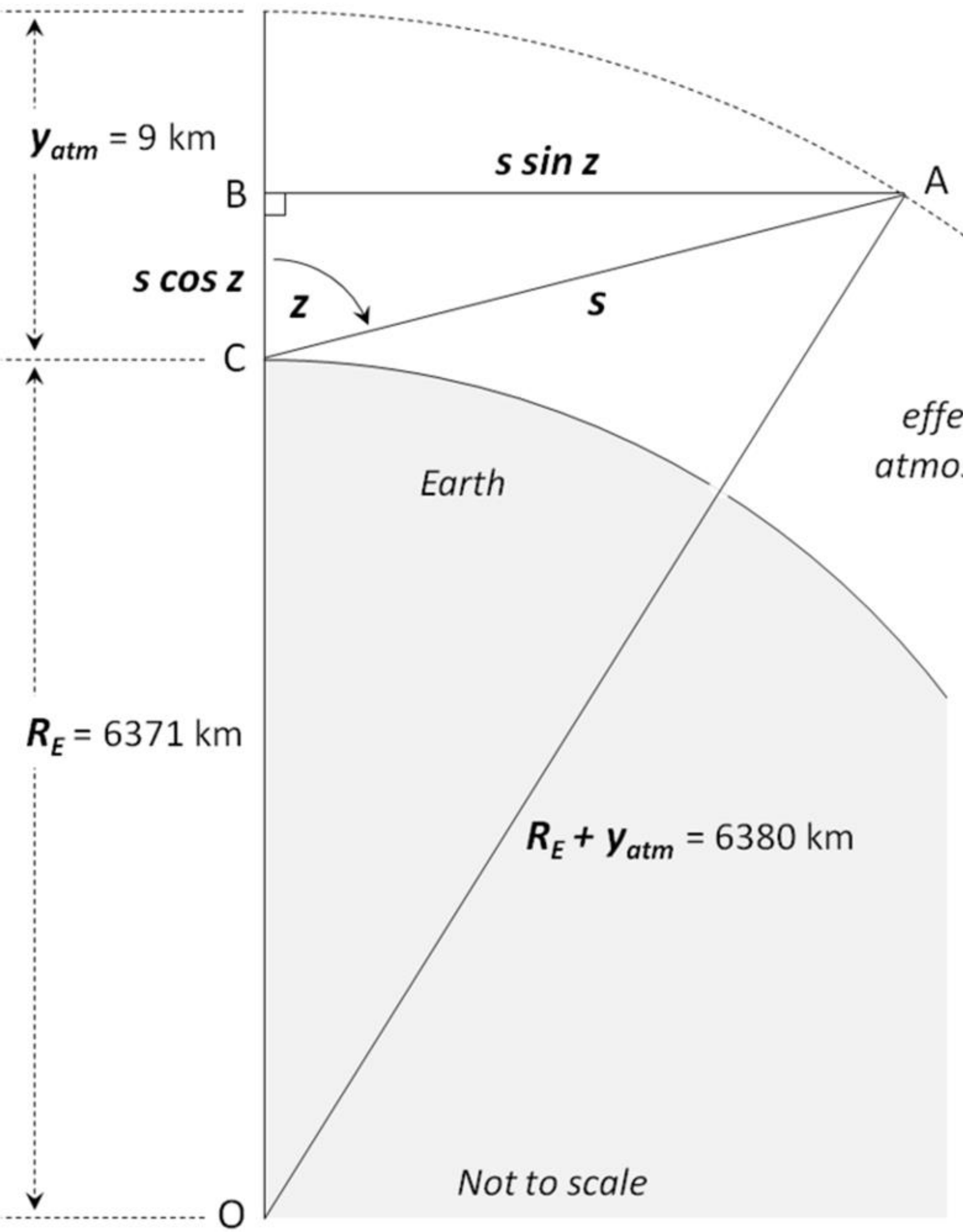
where the radius of the Earth R_{E} = 6371 km, the effective height of the atmosphere y_{atm} ≈ 9 km, and their ratio $r = R_{\mathrm{E}}/y_{\mathrm{atm}}$ ≈ 708.

These models are compared in the table below:

Estimates of airmass coefficient at sea level

z	Flat Earth	Kasten & Young	Spherical shell
degree	(A.1)	(A.2)	(A.3)
0°	1.0	1.0	1.0
60°	2.0	2.0	2.0
70°	2.9	2.9	2.9
75°	3.9	3.8	3.8
80°	5.8	5.6	5.6
85°	11.5	10.3	10.6
88°	28.7	19.4	20.3
90°	∞	37.9	37.6

https://en.wikipedia.org/wiki/Air_mass_(solar_energy)



i. Pythagoras applied to right-angle triangle OAB :

$$(R_E + y_{atm})^2 = (R_E + s \cos z)^2 + (s \sin z)^2$$

$$R_E^2 + 2\, R_E y_{atm} + y_{atm}^2 = R_E^2 + 2\, R_E s \cos z + s^2 \cos^2 z + s^2 \sin^2 z$$

$$R_E^2 + 2\, R_E y_{atm} + y_{atm}^2 = R_E^2 + 2\, R_E s \cos z + s^2 (\cos^2 z + \sin^2 z)$$

$$2\, R_E y_{atm} + y_{atm}^2 = 2\, R_E s \cos z + s^2$$

$$0 = s^2 + 2\, R_E\, s \cos z - (2\, R_E y_{atm} + y_{atm}^2)$$

ii. Solve quadratic for s :

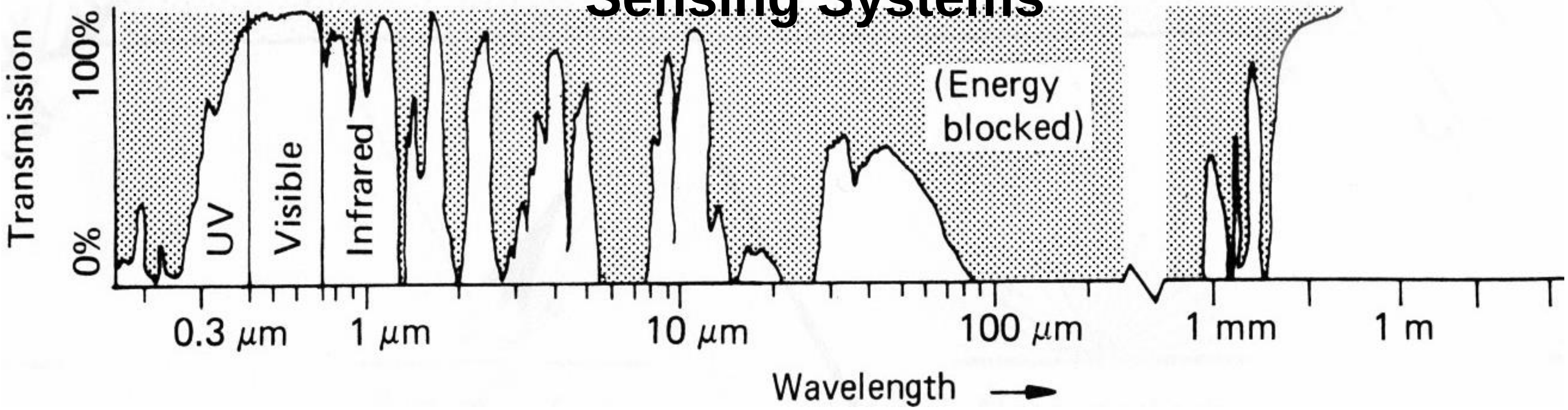
$$s = \{ -2\, R_E \cos z \pm \sqrt{[(2\, R_E \cos z)^2 + 4(2\, R_E y_{atm} + y_{atm}^2)]} \} / 2$$

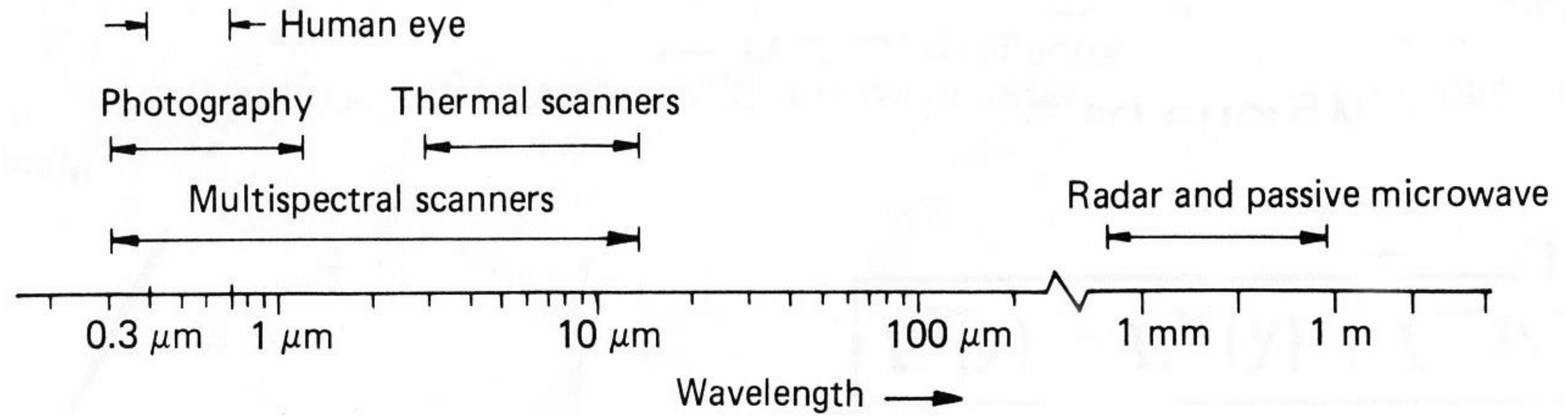
$$s = \sqrt{[(R_E \cos z)^2 + 2\, R_E y_{atm} + y_{atm}^2]} - R_E \cos z$$

$$AM = s / y_{atm} \quad ; \quad r = R_E / y_{atm} \approx 708$$

$$AM = \sqrt{[r^2 \cos^2 z + 2\, r + 1]} - r \cos z$$

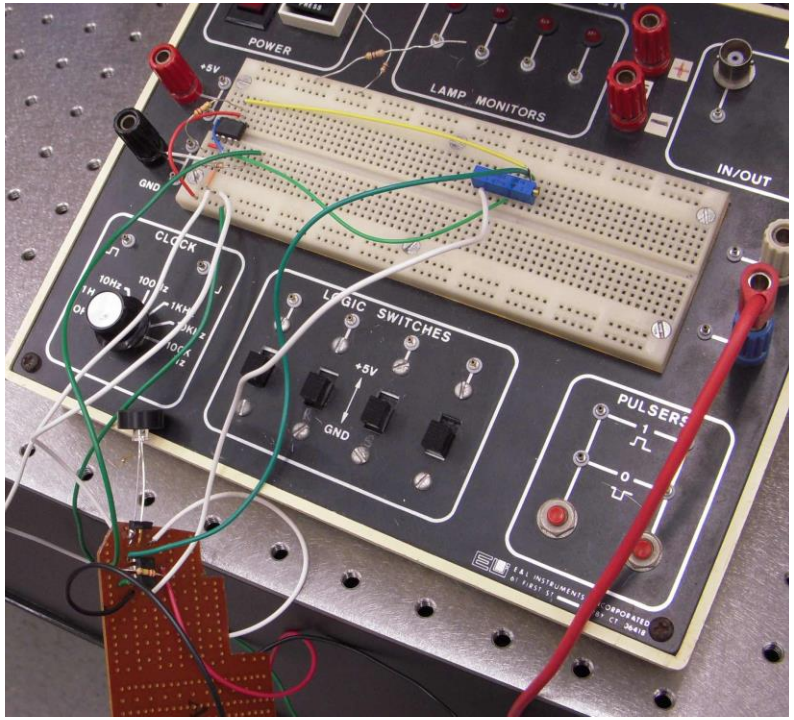
Spectral Characteristics of Atmospheric Transmission and Sensing Systems



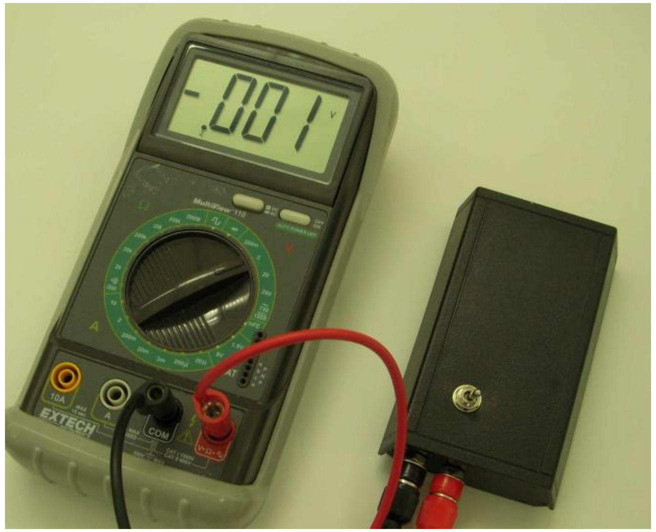


A sunphometer Class project done at UMBC

Sunphotometer: It all starts here



Final Project:



A peek inside

LED

OpAmp

hole

switch