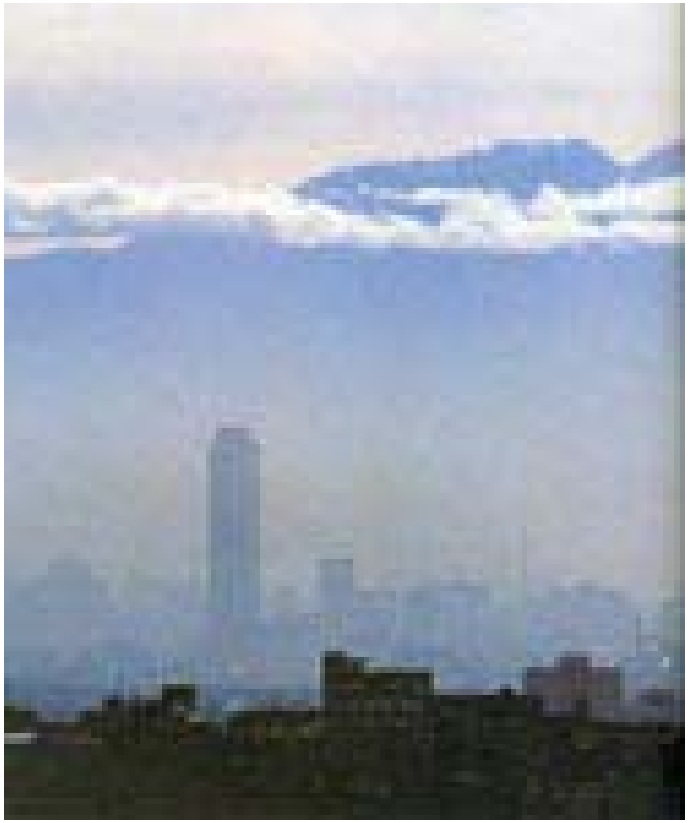
The Atmospheric Science Program: Aerosol Radiative Forcing for Fun & Profit!

Jeff Gaffney and Nancy Marley
Argonne National Laboratory



Mexico City

AEROSOLS - URBAN

PM-10 - <10 micrometer

PM-2.5 <2.5 micrometer

Primary –

Wind-blown dusts – Pollen, Spores, etc.

Carbonaceous soot – elemental or black C

Secondary -

Sulfate– Sulfuric Acid, Ammonium sulfate

Nitrate – Ammonium Nitrate

Organic Carbon – PAH, Oils, etc.

ATMOSPHERIC CHEMISTRY PROGRAM

ENVIRONMENTAL METEOROLOGY PROGRAM

JUNE 3, 2003

REFOCUS YOUR EFFORTS TOWARDS AEROSOL RADIATIVE EFFECTS

NOVEMBER 2003

BERAC SUBCOMMITTEE MEETING TO DEFINE THE FOCUS OF THE PROGRAM

DOE Program Officers

Mr. Peter Lunn

Mr. Rick Petty

Chief Scientist Named - March 1, 2004 – ASP

Steve Schwartz – Brookhaven National Laboratory

Leadership Team Named – March 4, 2004

Peter Daum – Brookhaven National Laboratory

Jeff Gaffney – Argonne National Laboratory

Steven Ghan – Pacific Northwest National Laboratory

CALL FOR PROPOSALS – JUNE 21, 2003 DUE DATE

Science Steering Committee to come from Science Team

Program Goals

The Atmospheric Science Program (ASP) has both a long-term goal, and a specific science focus that changes from time to time according to national and DOE needs. The long-term goal is to develop a comprehensive understanding of the atmospheric processes that control the transport, transformation, and fate of energy related chemicals and particulate matter, especially in the context of climate change.

Beginning in FY 2005 the specific science focus will be aerosol radiative forcing of climate. Associated with this focus is the objective of enhancing the scientific knowledge needed to simulate and predict radiative forcing and other climatic effects of aerosols.

Photochemical Smog Formation

CLIMATE EFFECTS OF FINE AEROSOLS

Light Scattering – Cooling (short wave)

Light Absorption – Heating (long wave- all aerosols!)

Carbonaceous Soot – short and long wave

Indirect – Cloud Condensation Nuclei – Increased Clouds to HAZY SKIES – Depending upon Concentration and Composition.

IMPACT DEPENDS ON POSITION IN THE ATMOSPHERE AND THEIR LIFETIMES

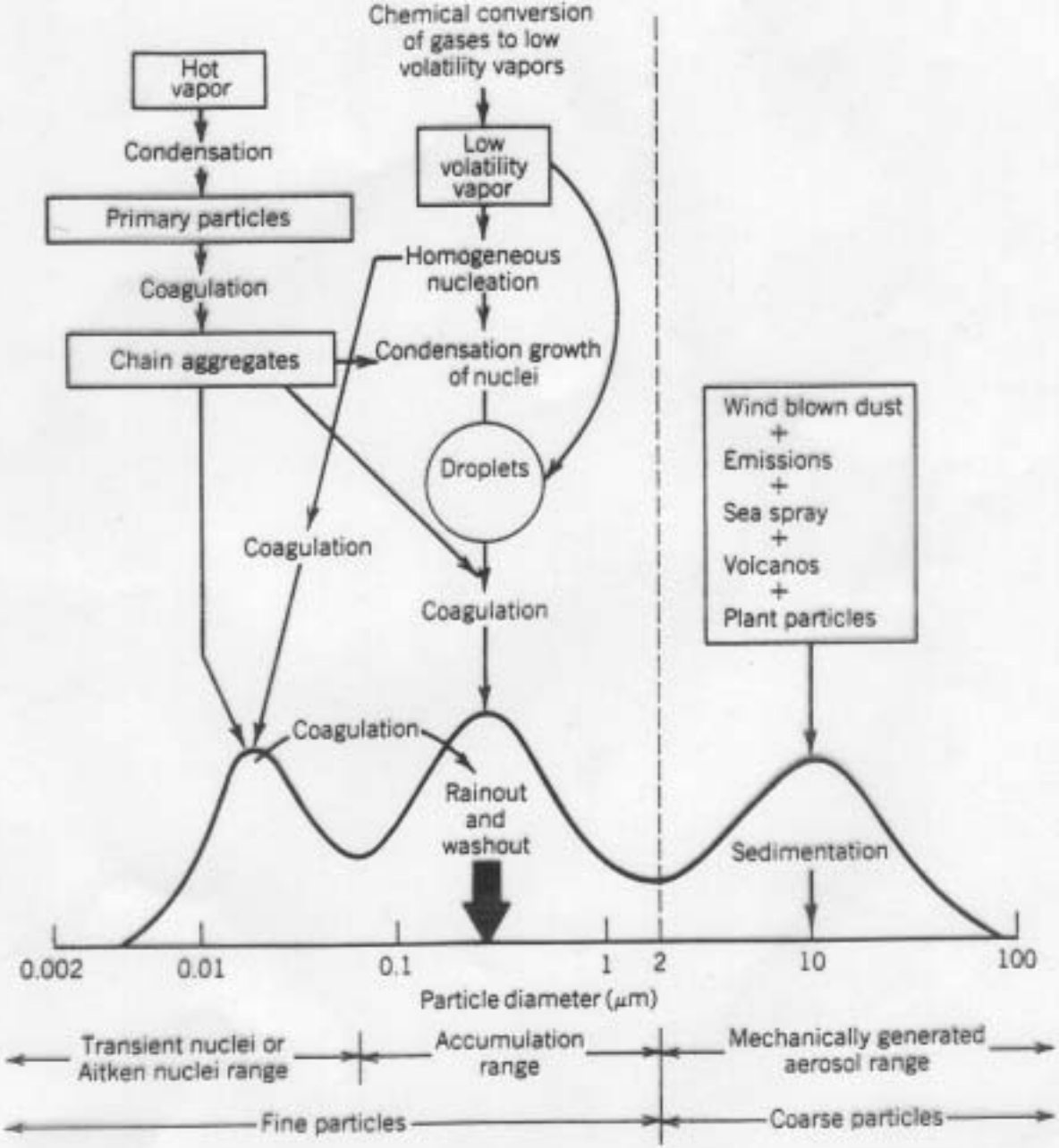
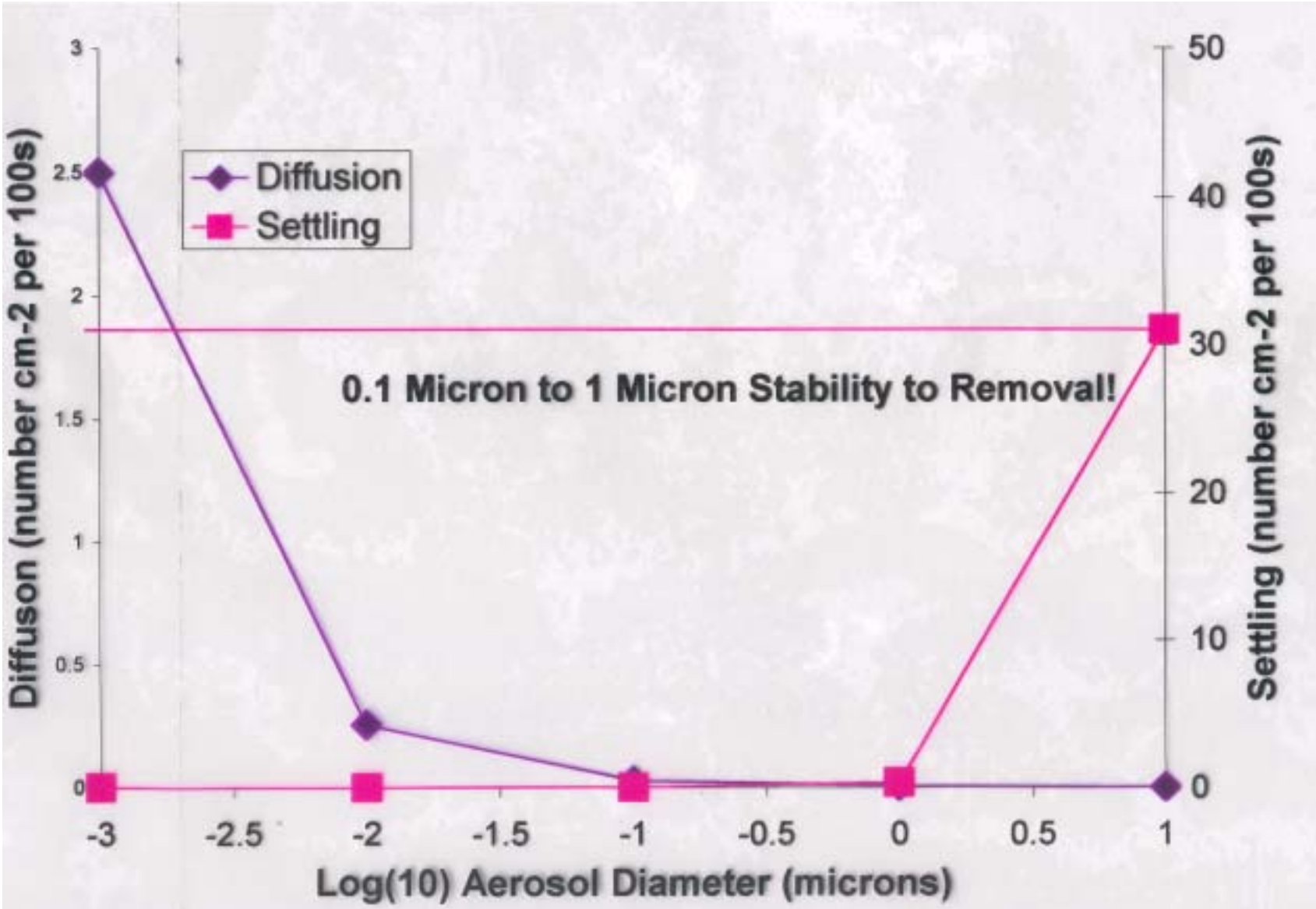


FIGURE 12.9. Schematic of an atmospheric aerosol size distribution showing the three modes, the main source of mass for each mode, and the principal processes involved in inserting mass into and removing mass from each mode (from Whitby and Sverdrup, 1980).


Diffusion
Settling
0.1 Micron to 1 Micron Stability to Removal!
Diffuson (number cm-2 per 100s)
Settling (number cm-2 per 100s)
Log(10) Aerosol Diameter (microns)
3
2.5
2
1.5
1
0.5
0
50
40
30
20
10
0
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1

Atmospheric Science Program:

DOE Research Aircraft Facility

Gulfstream 159 Aircraft for Airborne Atmospheric Research

DOE Research Aircraft Facility

DOE Research Aircraft Facility

Dave Turner

Attributes of the G-1

Research Electrical Power

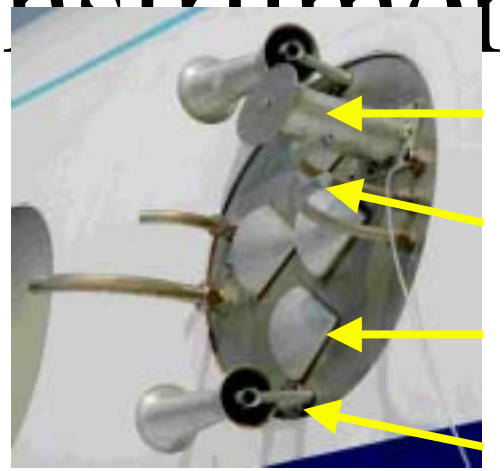
Instrumentation on G-1

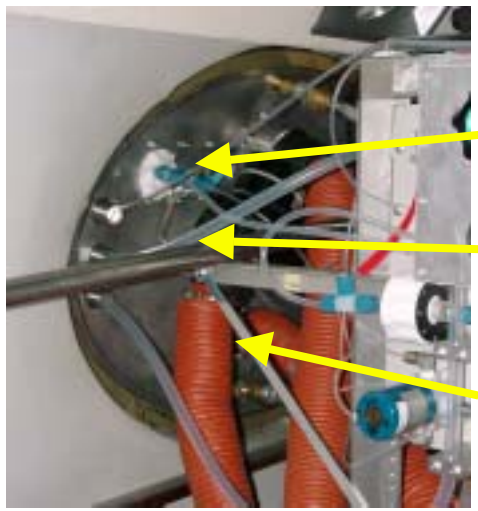
Instrumentation on G-1
(continued)

Instrumentation on G-1
(continued)

Instrumentation on G-1
(continued)

Inlets and Exhausts for Research Instruments

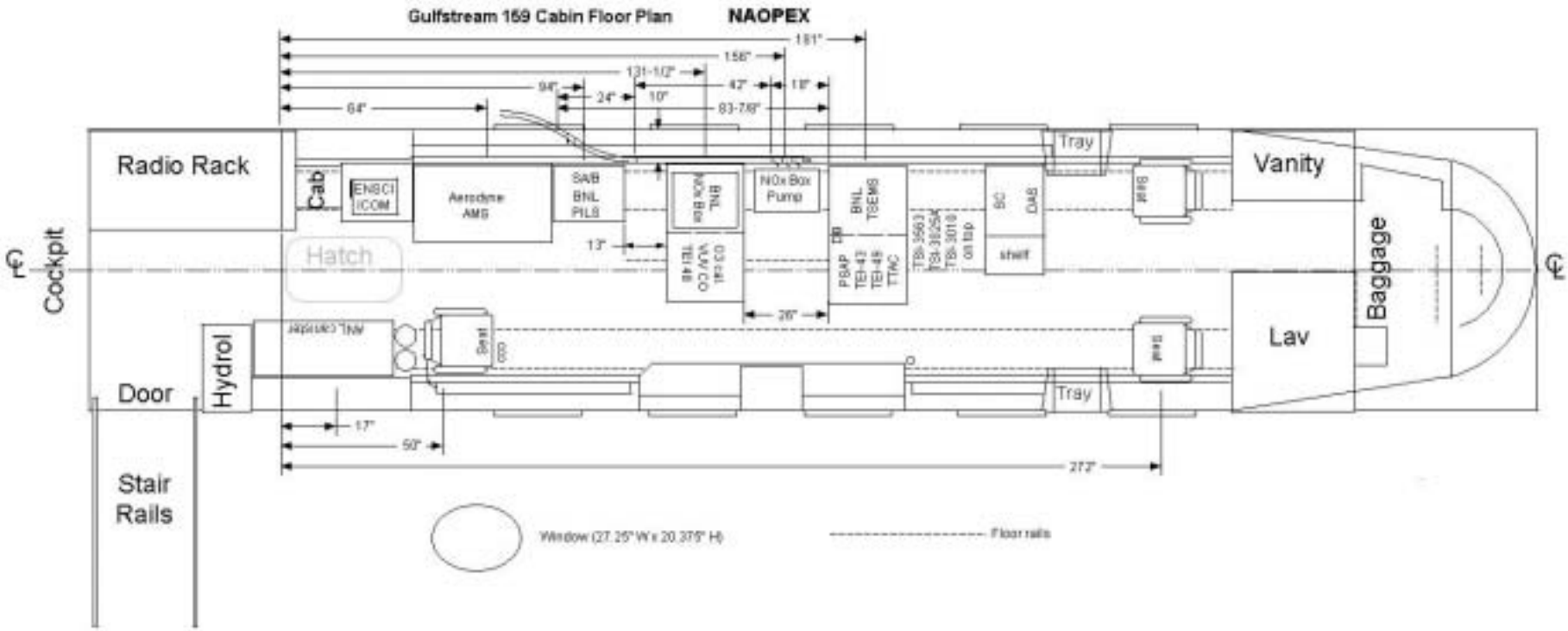




Instrumentation Racks

Data Acquisition System

Cabin Configuration for



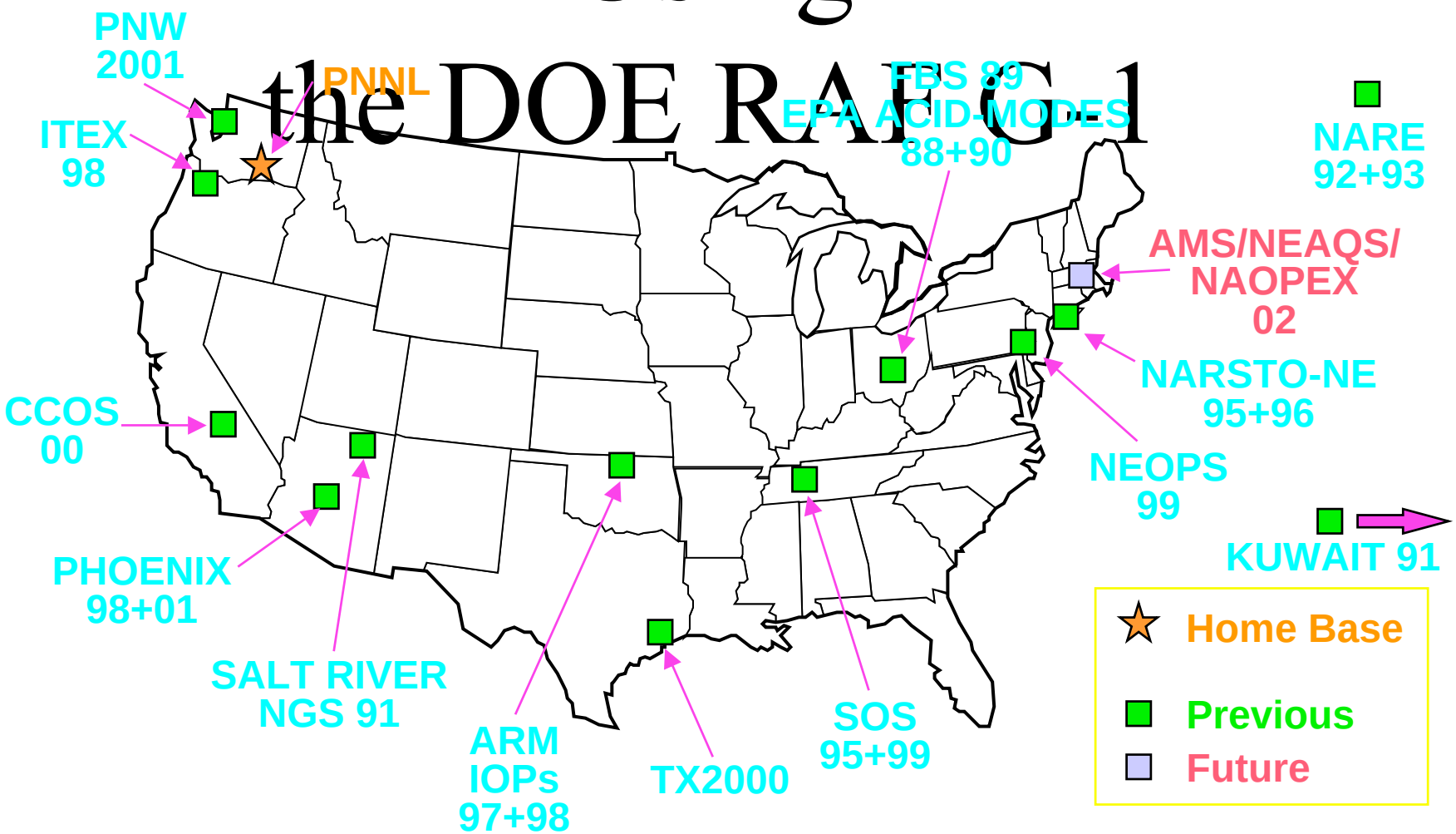
2700 lb equipment

4 scientific crew

5000 VA @ 110 VAC

2900 VA @ 220 VAC

Locations of ACP Projects Using the DOE RAFG-1



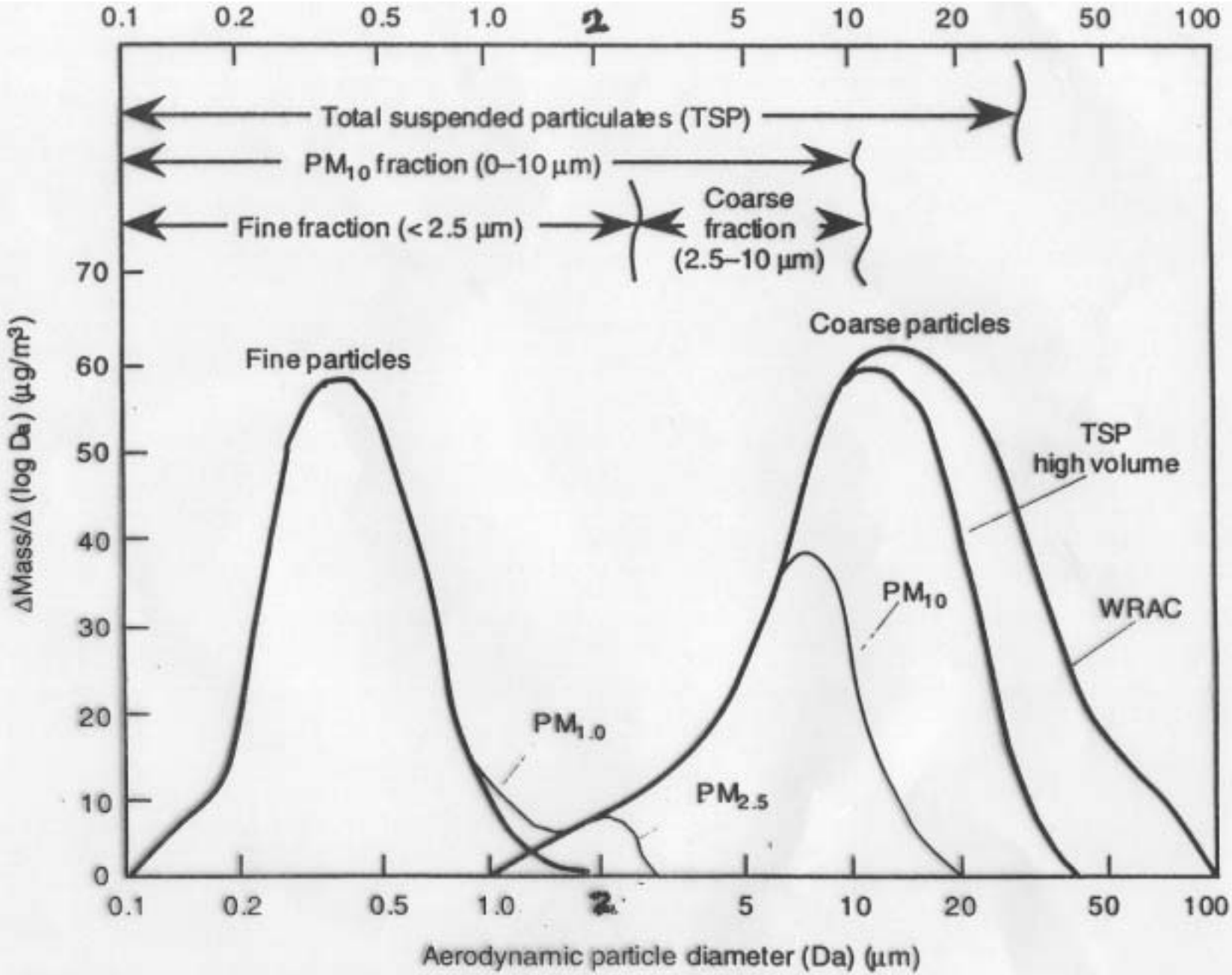
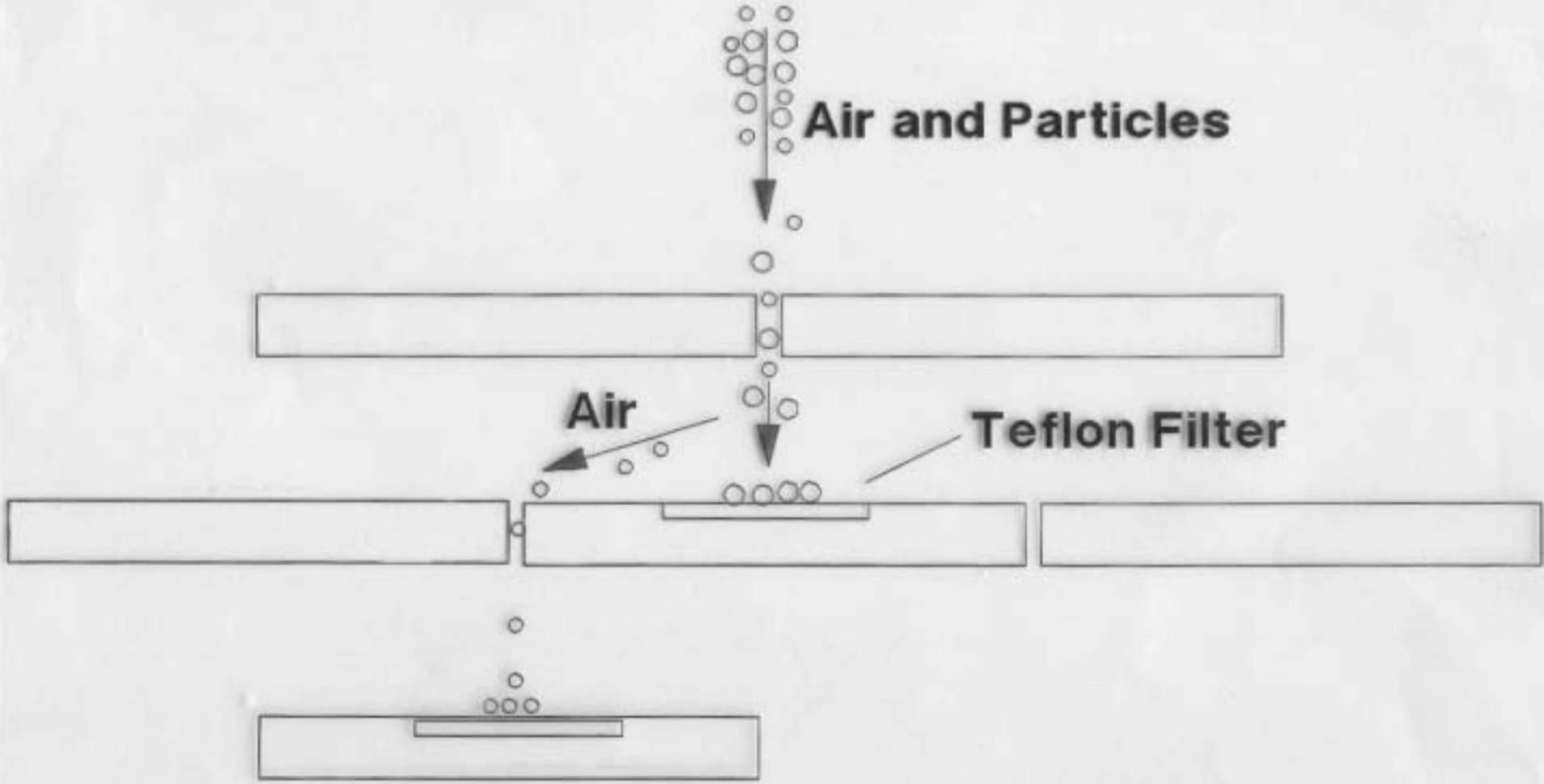
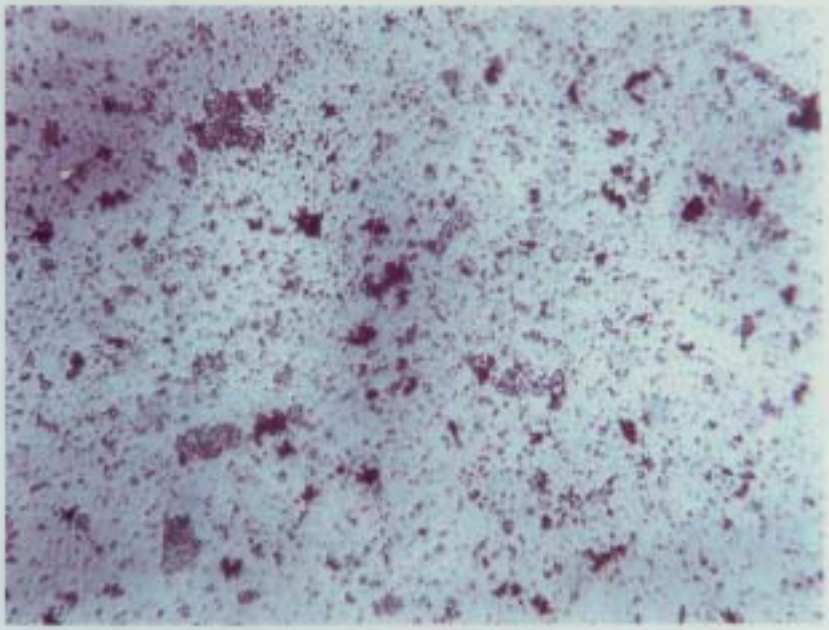


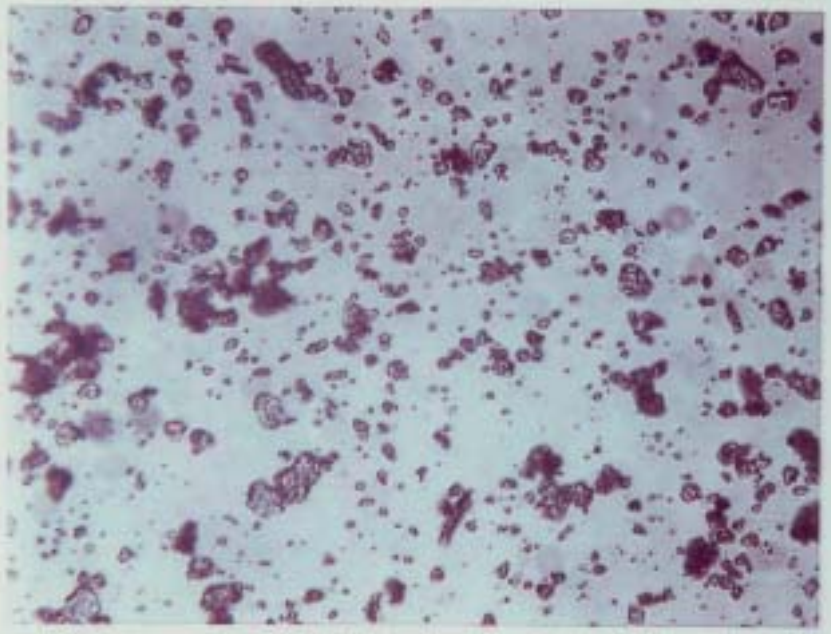
Figure 5
The interrelationship between different parameters used to describe the size distribution of airborne particulate matter. (Adapted from Wilson and Suh, 1997.)

BASIC PHYSICS OF AN IMPACTOR

Sizing Dependent on Flow Velocity and Geometry



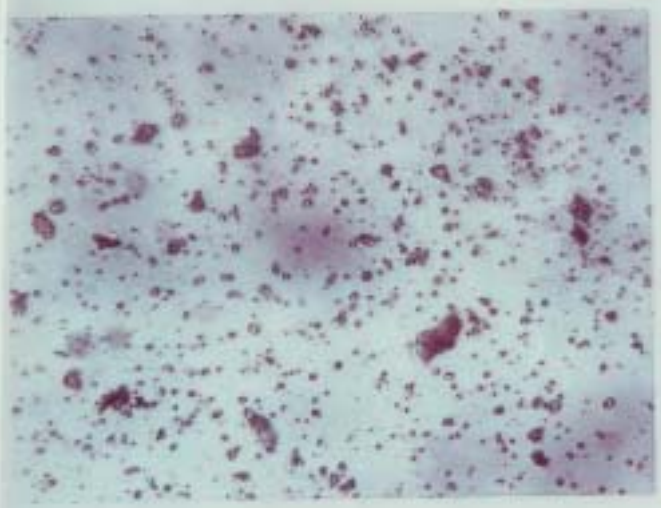


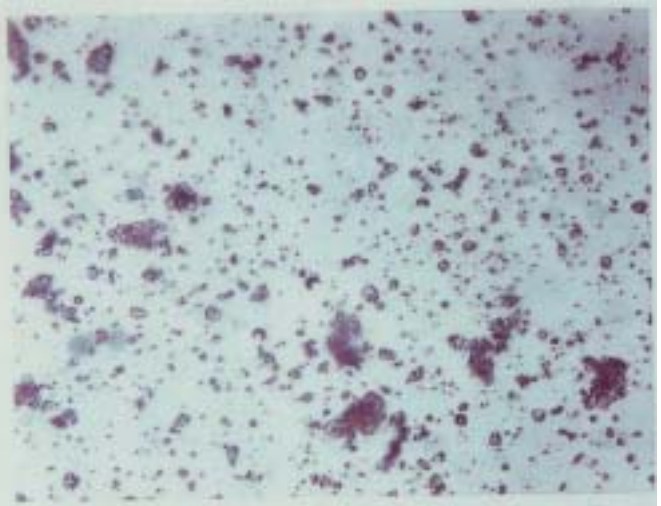


STAGE 5
50% CUTOFF 0.5 µm

STAGE 4
50% CUTOFF 1.0 µm

1 cm = 25µm





STAGE 3
50% CUTOFF 2.0 µm

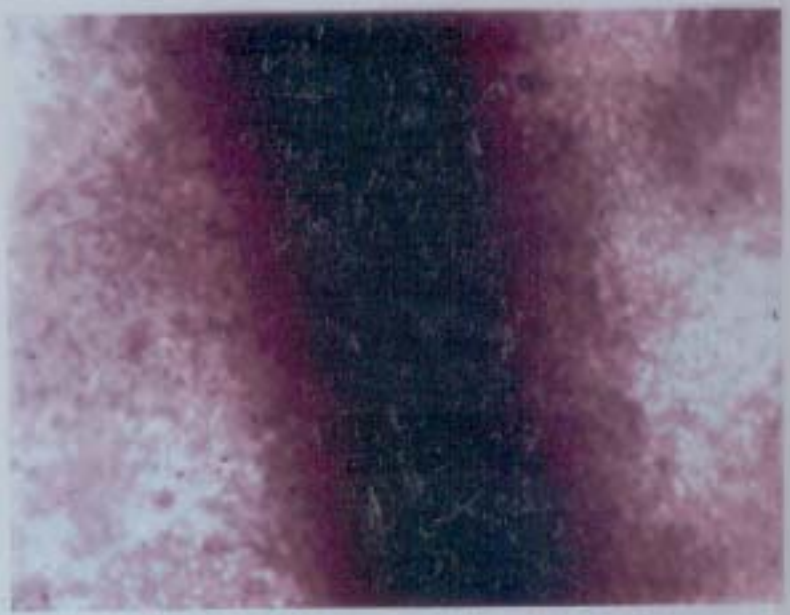
STAGE 2
50% CUTOFF 4.0 µm

1 cm = 25µm

Aerosol Samples - Argonne, IL

1 cm = 25 um

1 cm = 158 um



Size Fraction 5; 0.5 um.

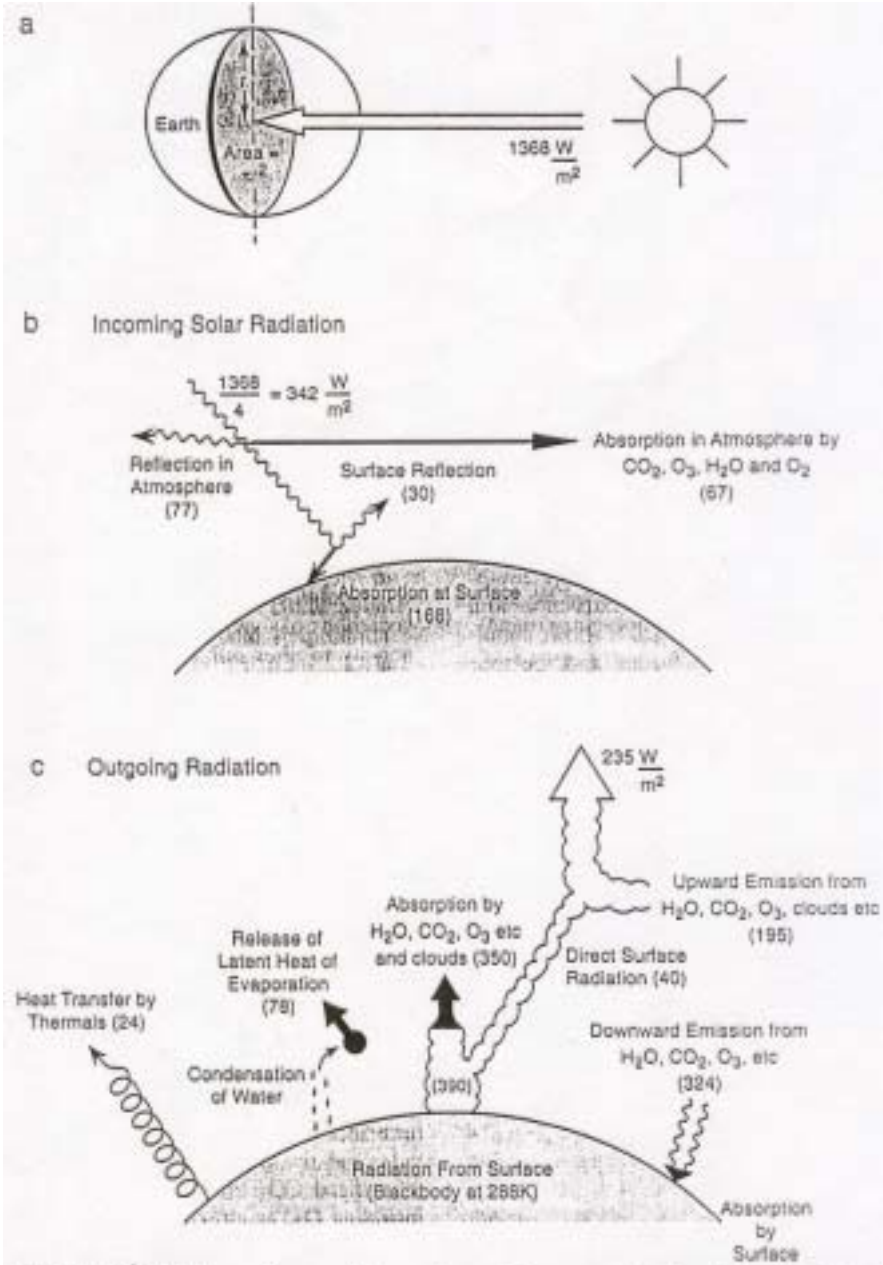
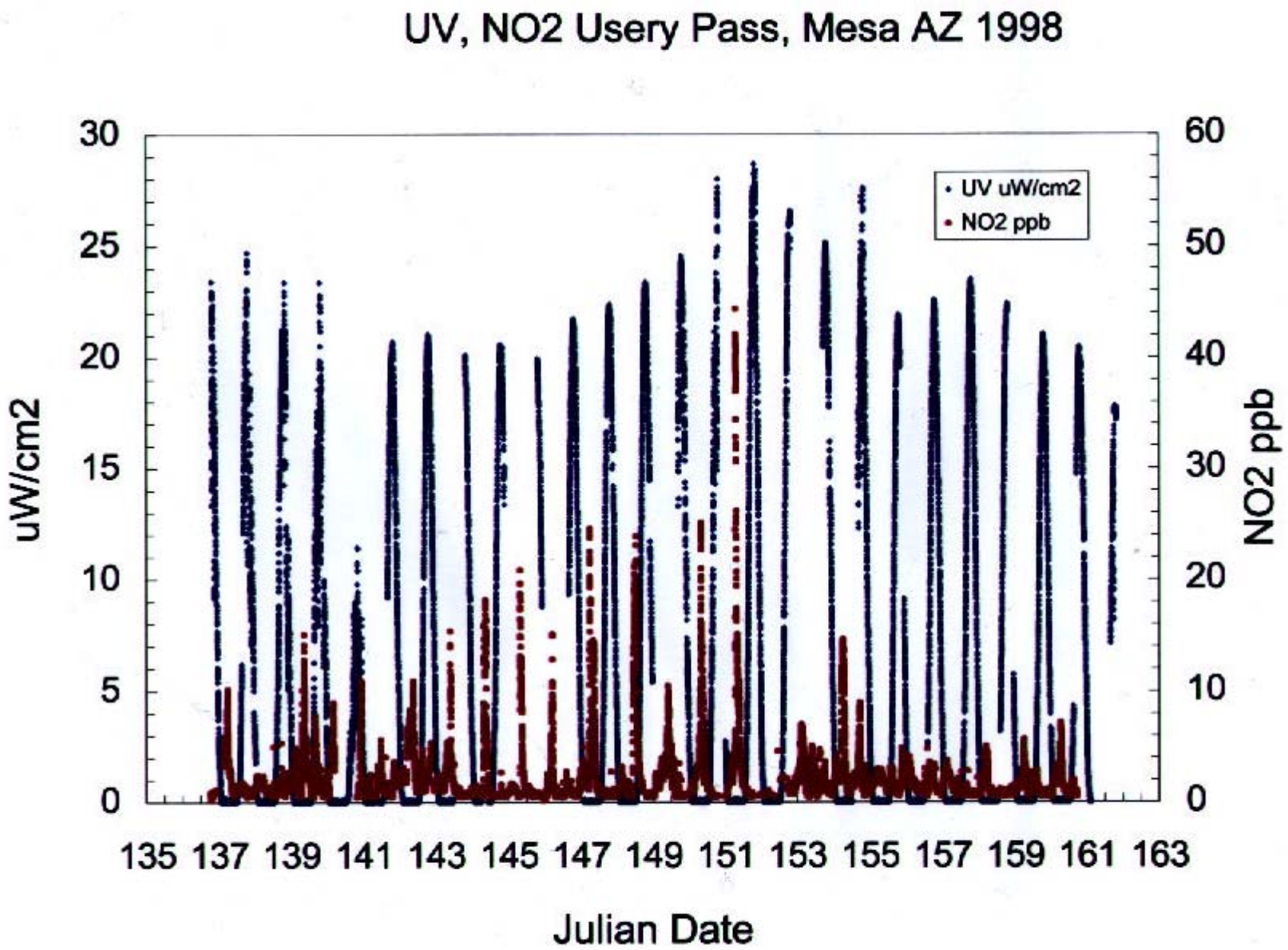
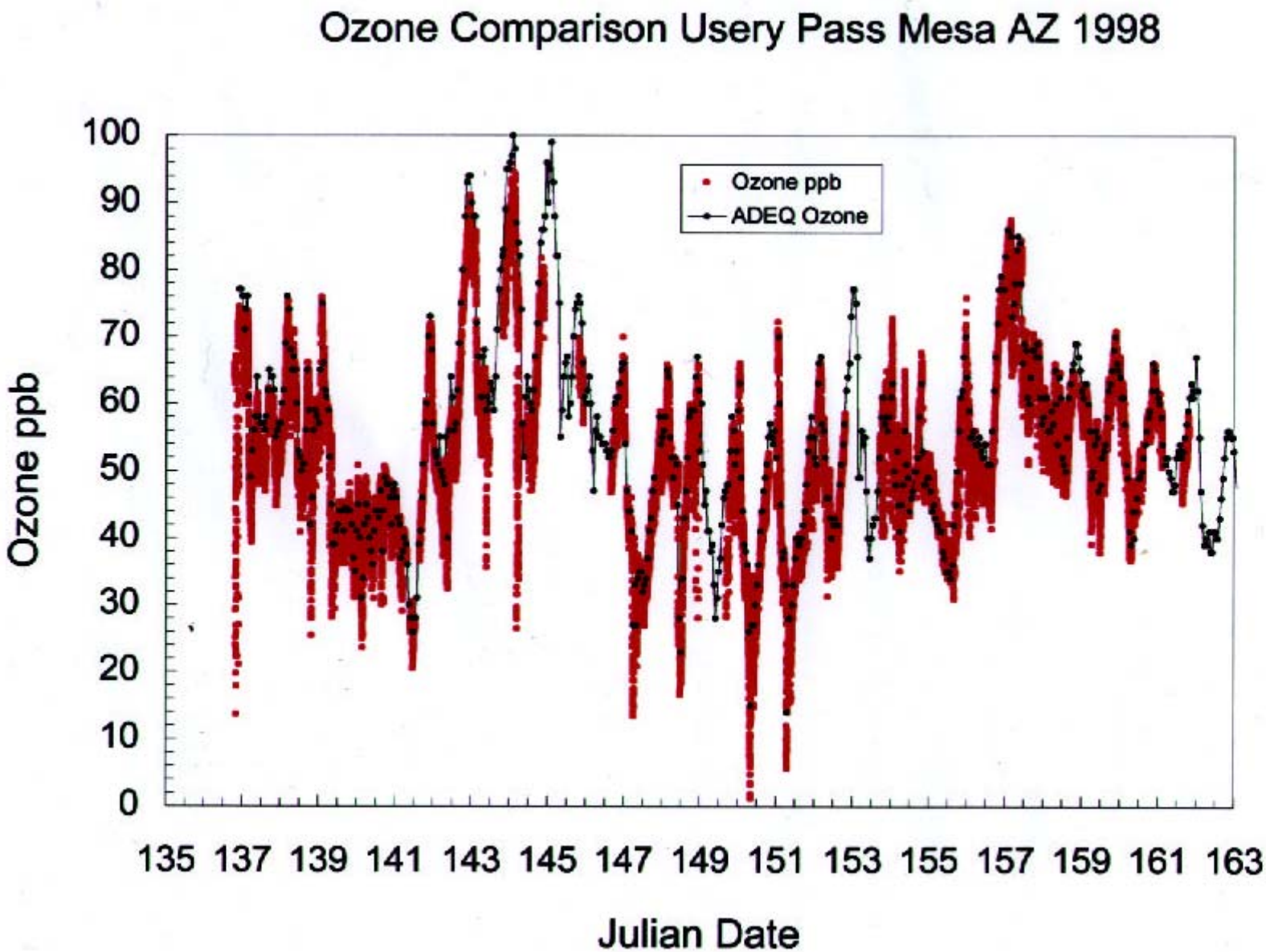
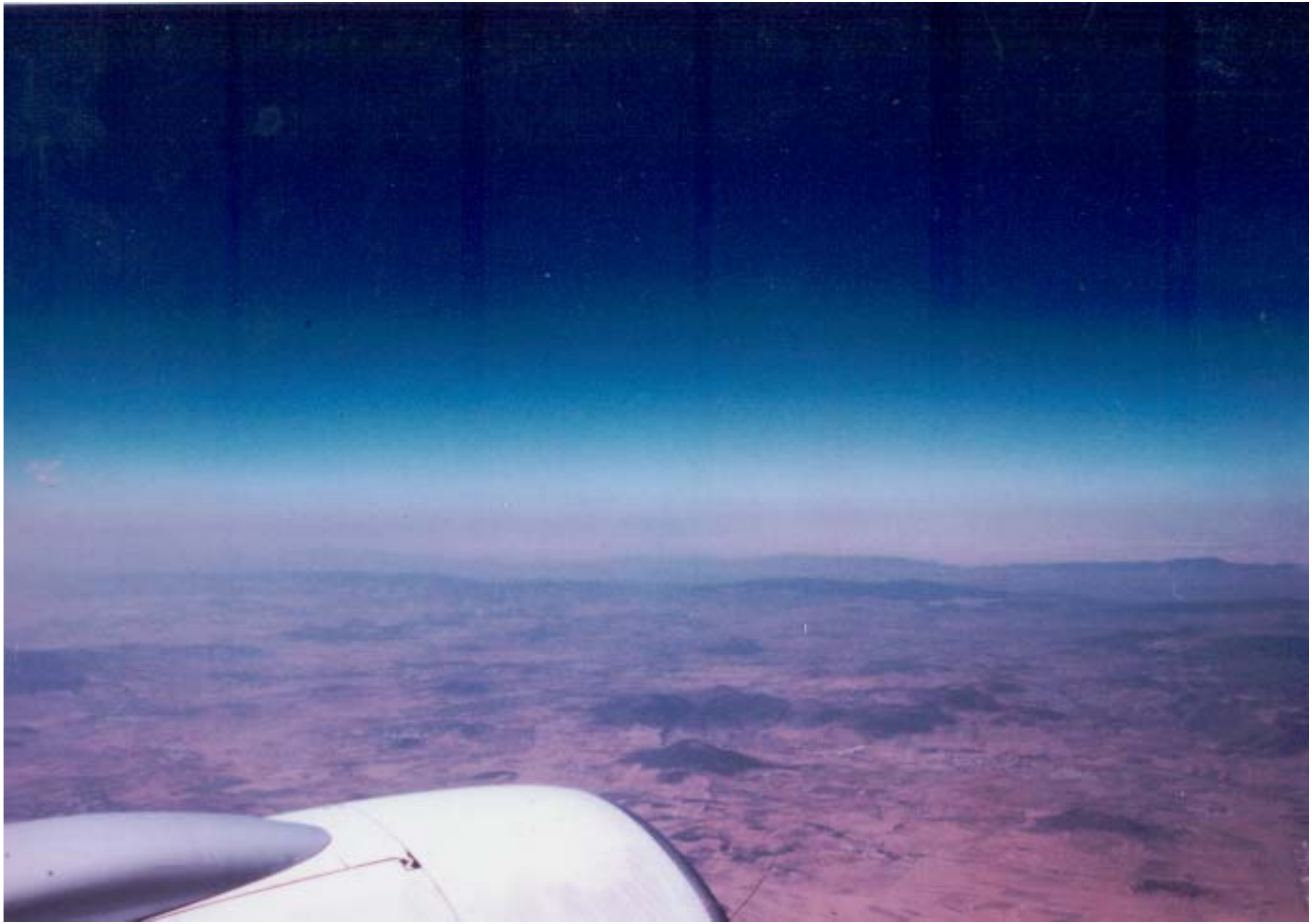


FIGURE 1.9 Global average mean radiation and energy balance per unit of earth's surface [adapted with permission from IPCC (1996) with numbers from Kiehl and Trenberth (1997)].


UV, NO2 Usery Pass, Mesa AZ 1998
UV uW/cm2
NO2 ppb
uW/cm2
NO2 ppb
Julian Date
0
5
10
15
20
25
30
0
10
20
30
40
50
60
135 137 139 141 143 145 147 149 151 153 155 157 159 161 163


Ozone Comparison Usery Pass Mesa AZ 1998
Ozone ppb
ADEQ Ozone
Ozone ppb
100
90
80
70
60
50
40
30
20
10
0
135 137 139 141 143 145 147 149 151 153 155 157 159 161 163
Julian Date



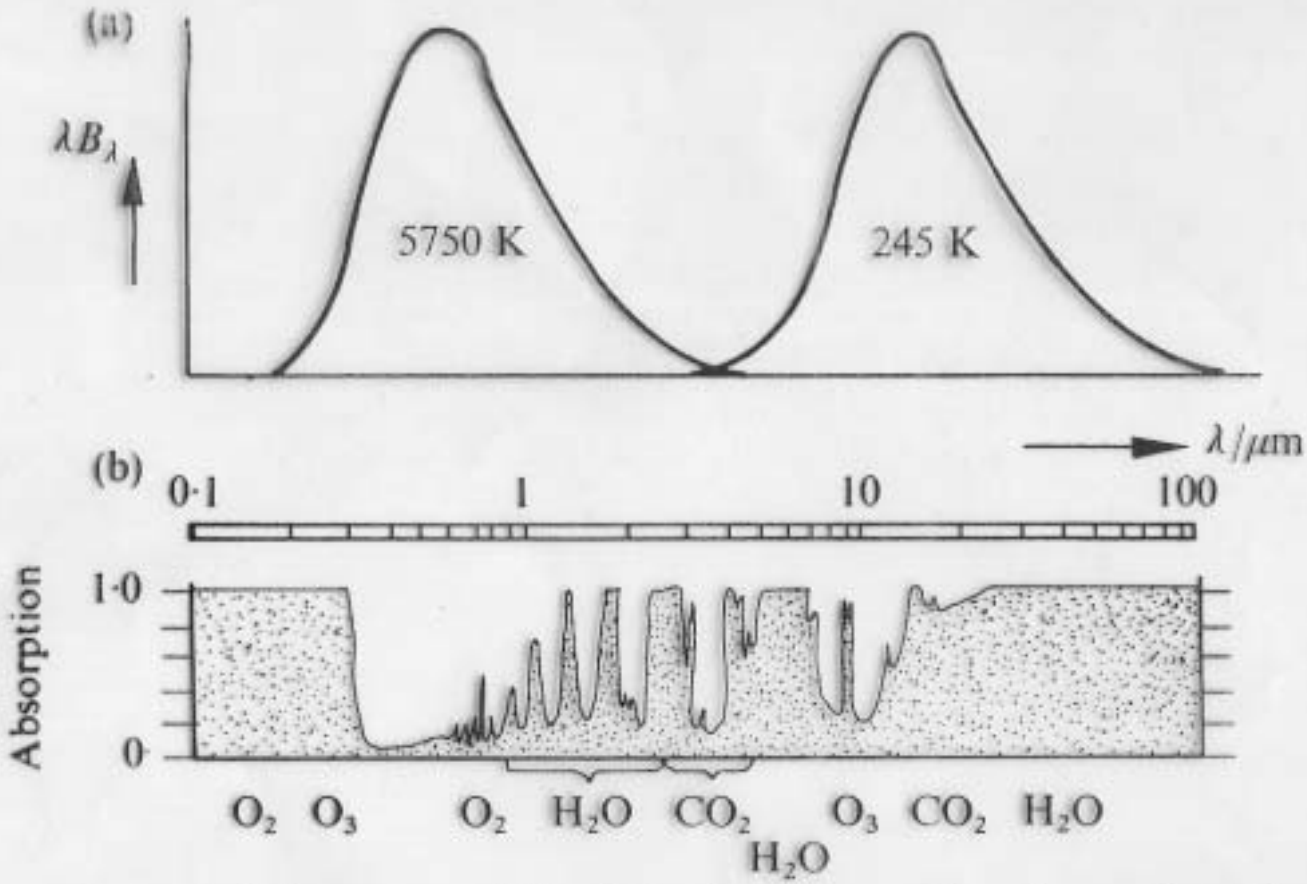
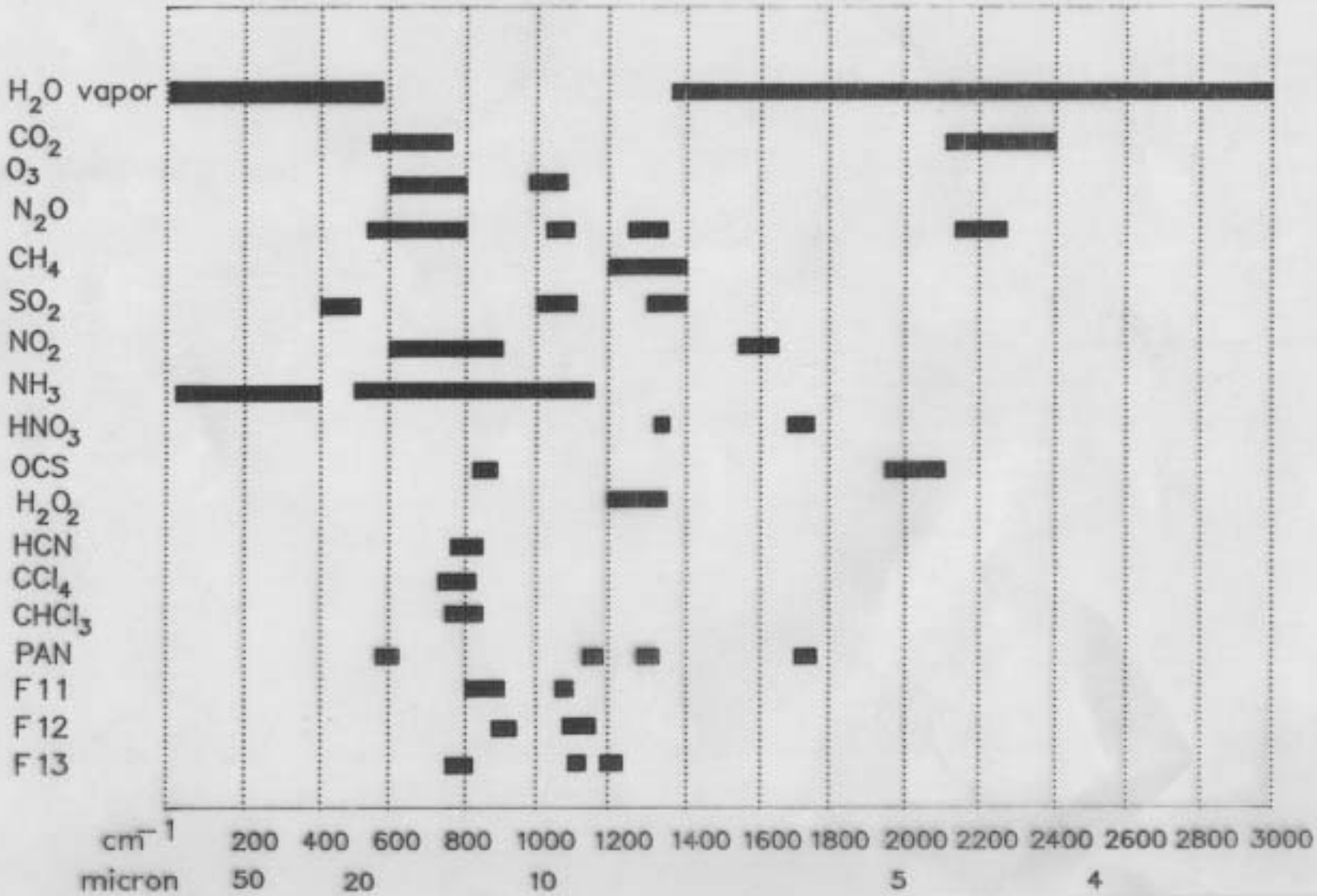
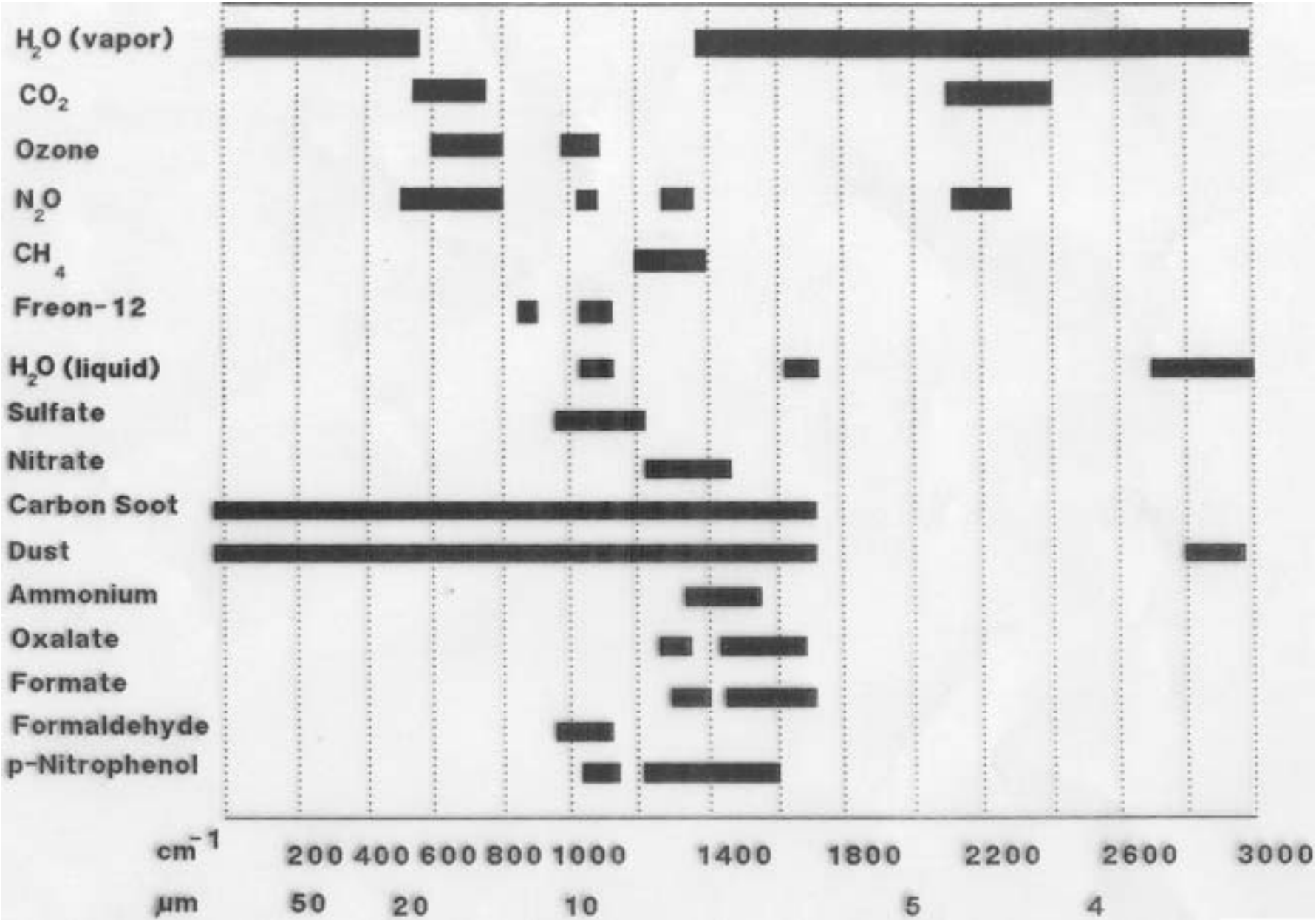
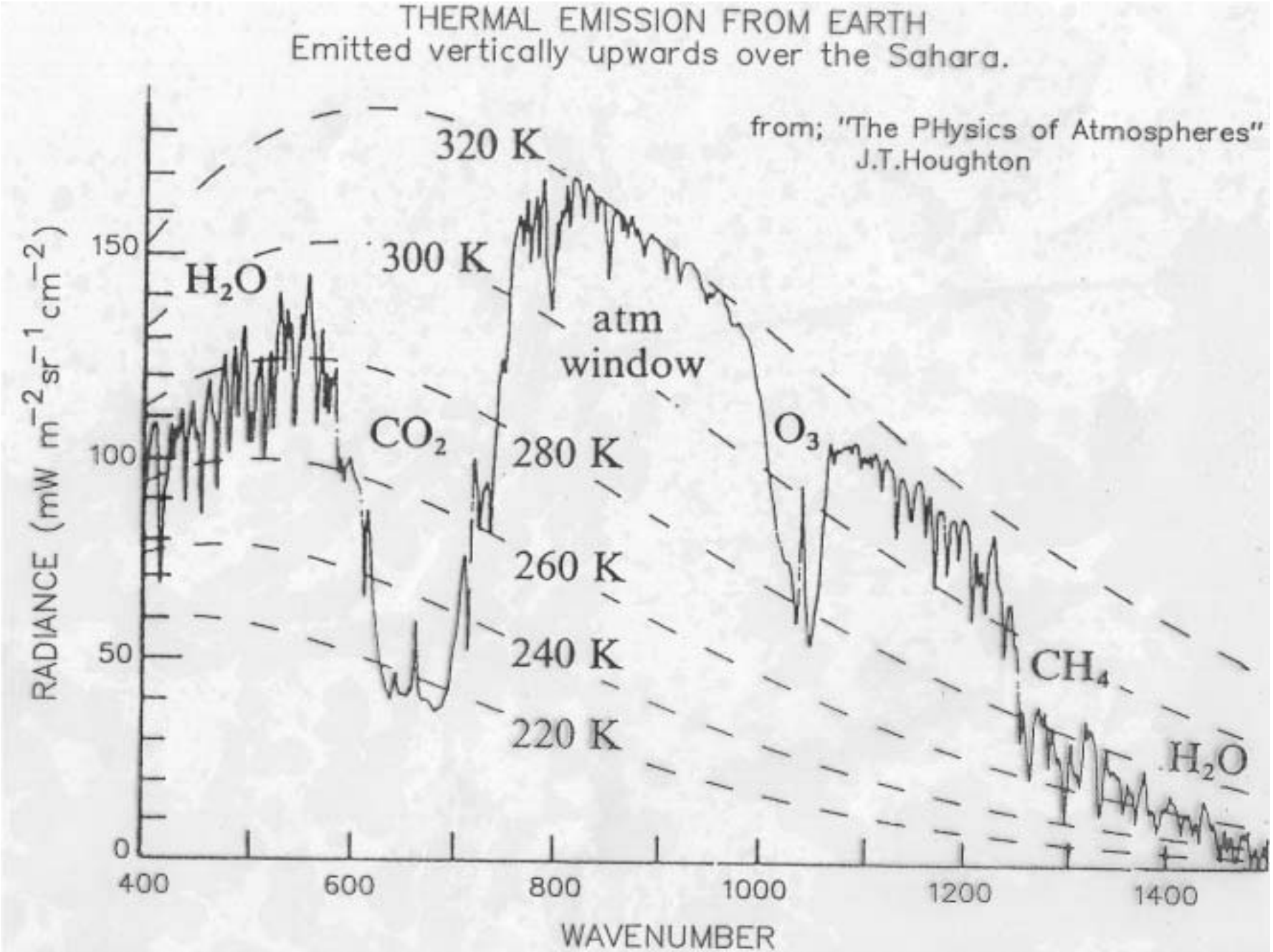


Fig. 2.1. (a) Curves of black-body energy B_λ at wavelength λ for 5750 K (approximating to the sun's temperature) and 245 K (approximating to the atmosphere's mean temperature). The curves have been drawn of equal areas since integrated over the earth's surface and all angles the solar and terrestrial fluxes are equal.
(b) Absorption by atmospheric gases for a clear vertical column of atmosphere. The positions of the absorption bands of the main constituents are marked.

SPECTRAL LOCATIONS OF THE MAJOR INFRARED ABSORPTION BANDSFOR THE GREENHOUSE GASSES




H_2O (vapor)
CO_2
Ozone
N_2O
CH_4
Freon-12
H_2O (liquid)
Sulfate
Nitrate
Carbon Soot
Dust
Ammonium
Oxalate
Formate
Formaldehyde
p-Nitrophenol
cm^{-1}
200 400 600 800 1000 1400 1800 2200 2600 3000
µm
50 20 10 5 4


THERMAL EMISSION FROM EARTH
Emitted vertically upwards over the Sahara.
from; "The PHysics of Atmospheres"
J.T.Houghton
320 K
300 K
280 K
260 K
240 K
220 K
H_2O
CO_2
atm
window
O_3
CH_4
H_2O
RADIANCE (mW $m^{-2}sr^{-1}cm^{-2}$)
150
100
50
0
400
600
800
1000
1200
1400
WAVENUMBER

SOME ISSUES

ATMOSPHERIC LIFETIMES

- Course Aerosol - Hours
- Fine Aerosols - Days, Months?

LOCAL SOURCE EMISSION CONTROLS?

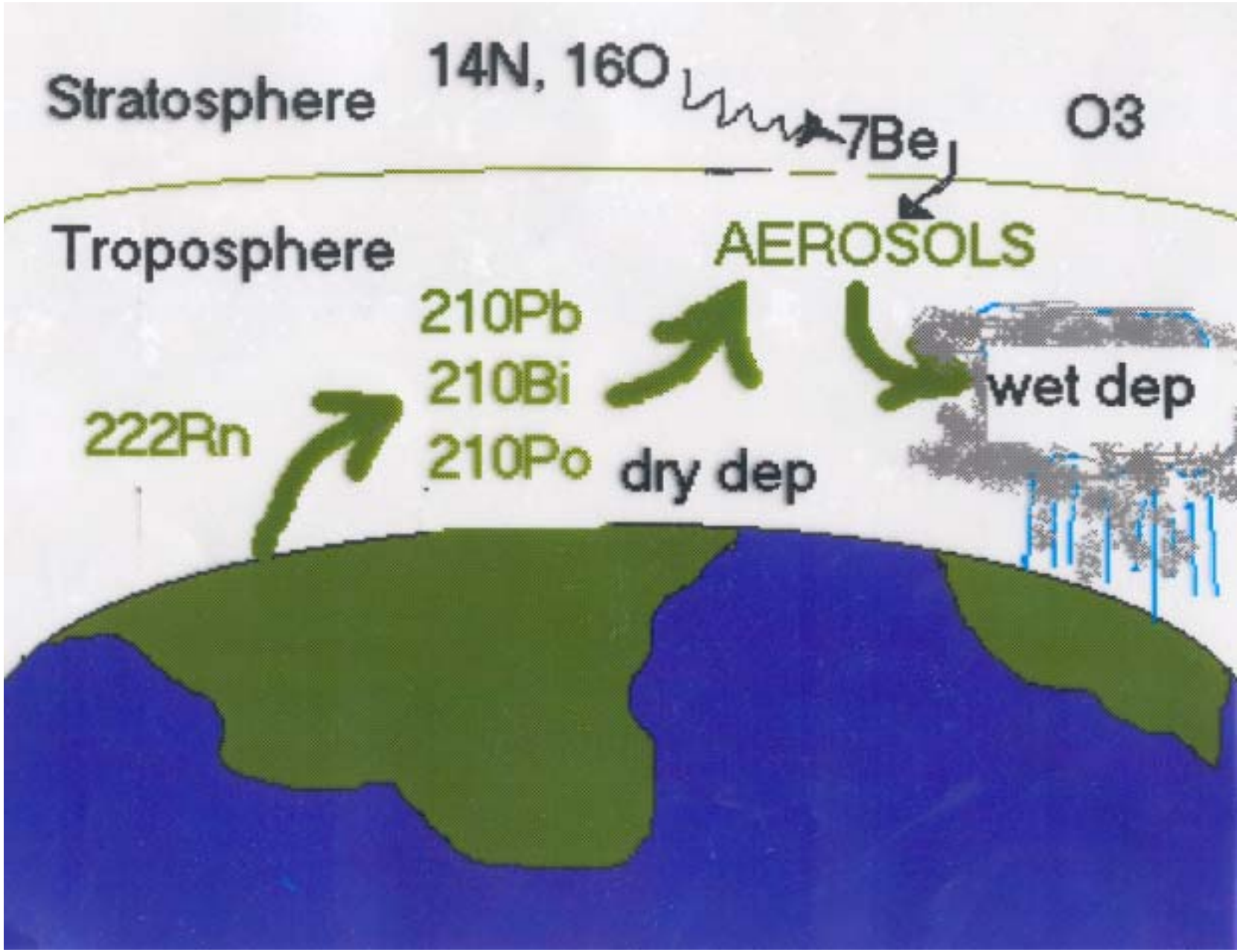
REGIONAL EMISSION CONTROLS?

COMBUSTION SOURCES - CARBONACEOUS AEROSOL

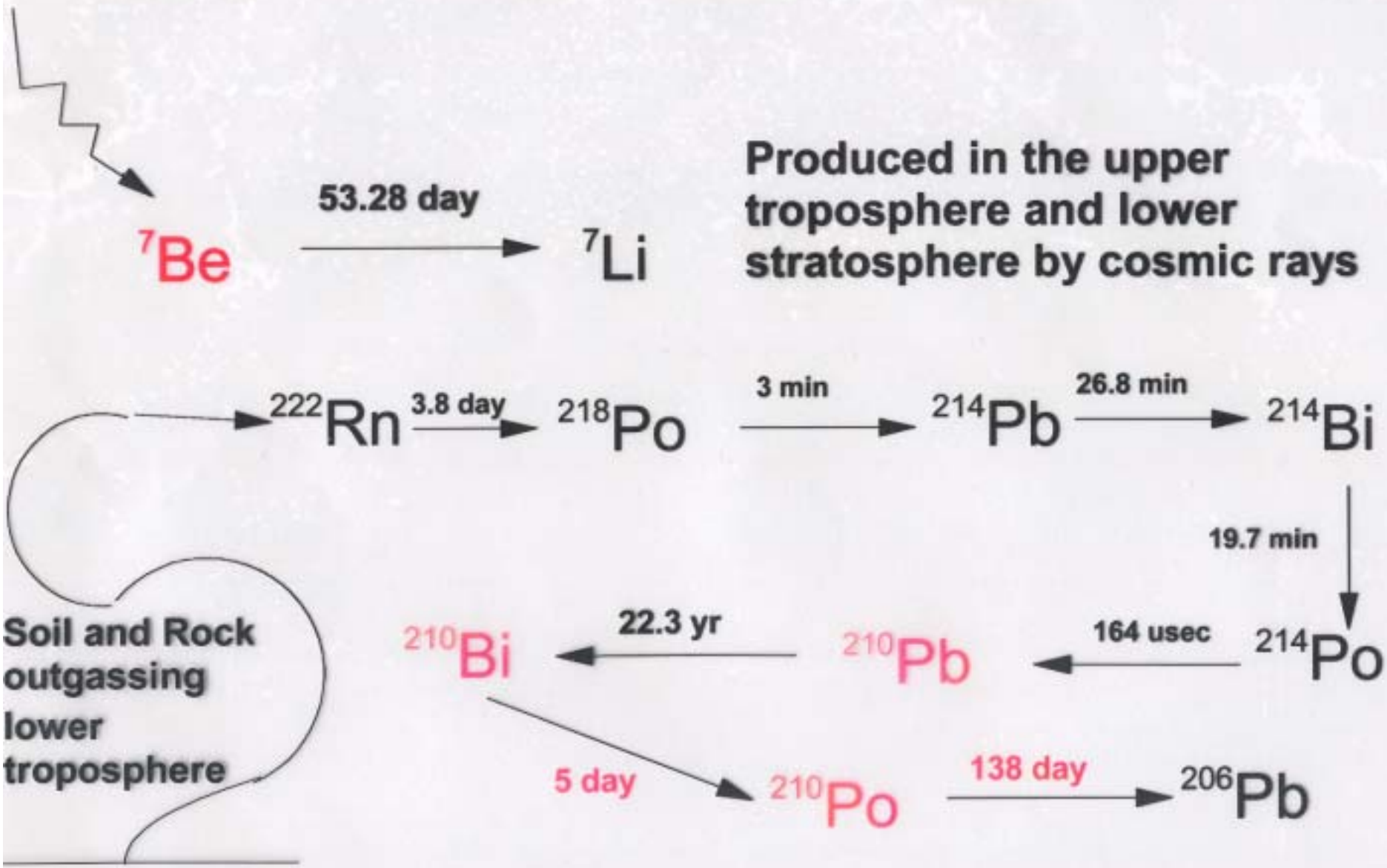
- Diesel Engines
- Jet Engines
- Incineration of Wastes

PM-2.5 & AIR TOXICS

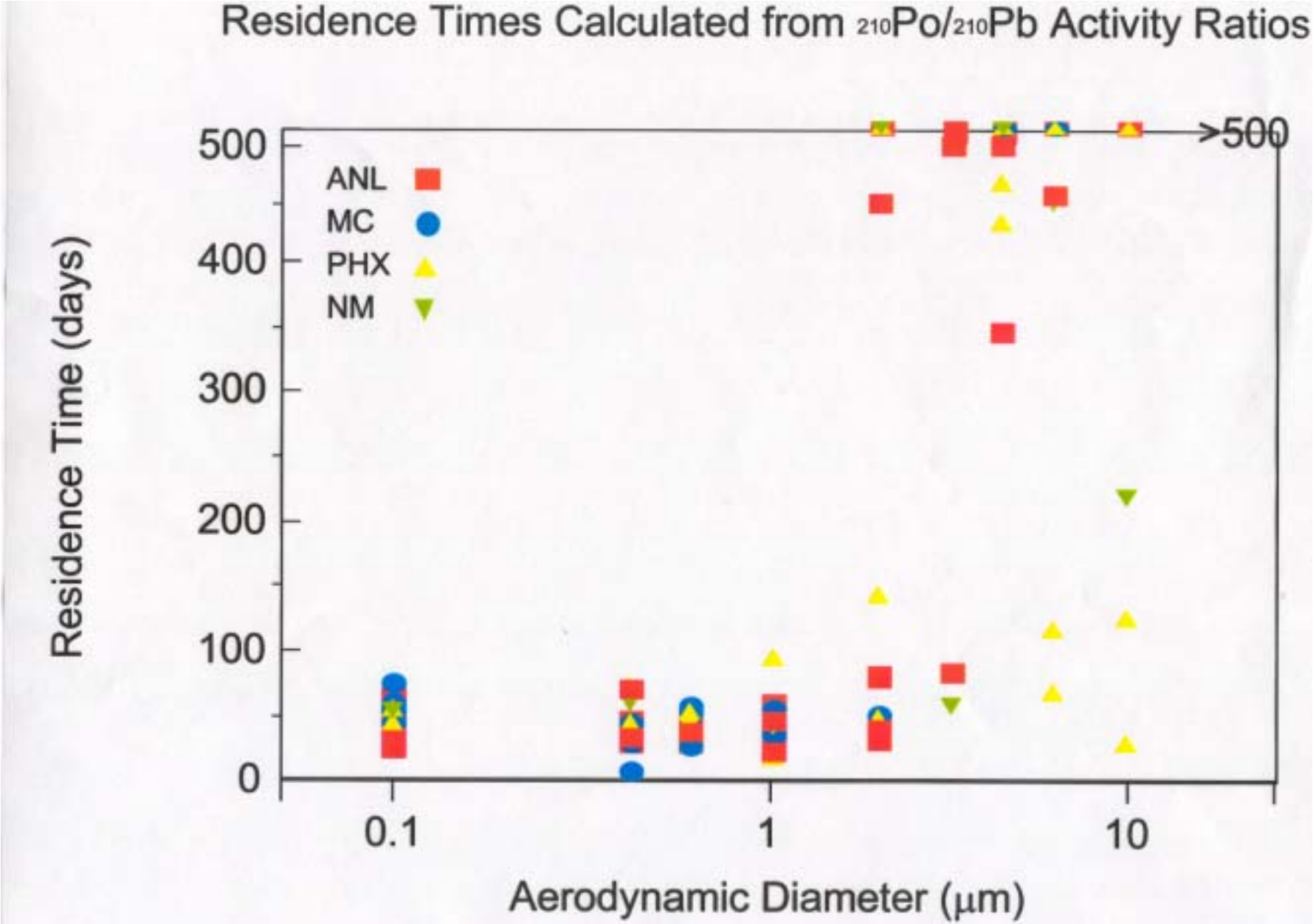
- Toxic Metals
- PAH, PCBs, etc.


Stratosphere
14N, 16O
7Be
O3
Troposphere
AEROSOLS
210Pb
210Bi
210Po
222Rn
dry dep
wet dep

Radioactive Decay of Natural Atmospheric Tracers



4/4/2002 20:03

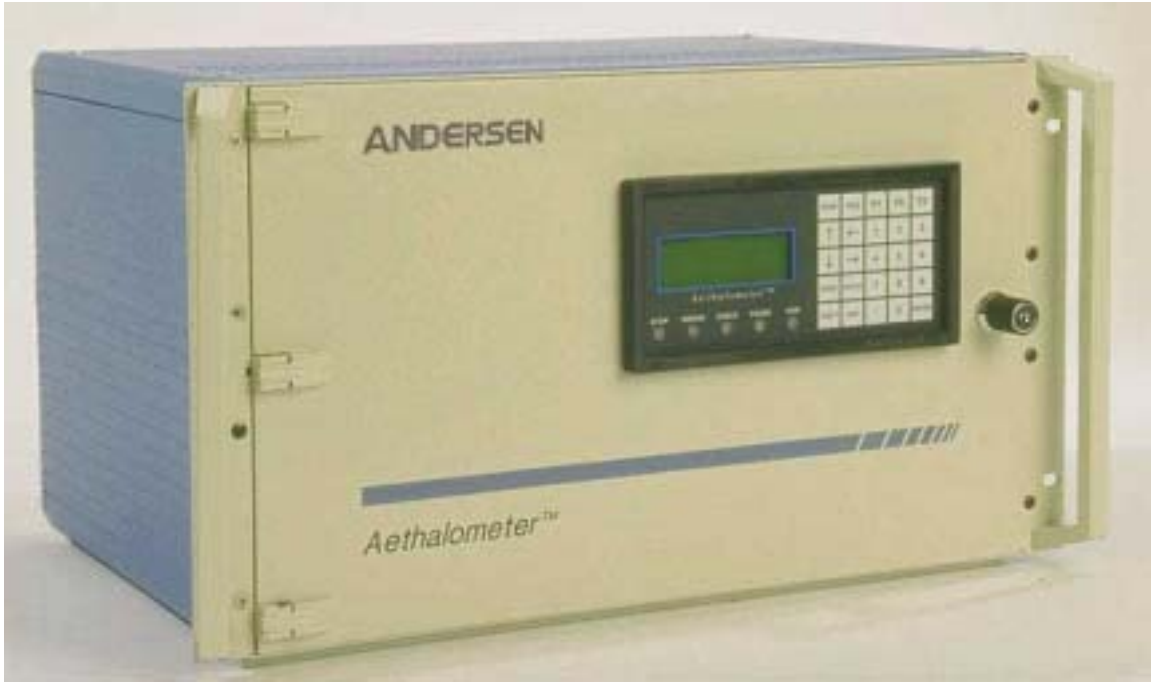

Residence Times Calculated from 210Po/210Pb Activity Ratios
ANL
MC
PHX
NM
>500
500
400
300
200
100
0
Residence Time (days)
0.1
1
10
Aerodynamic Diameter (μm)

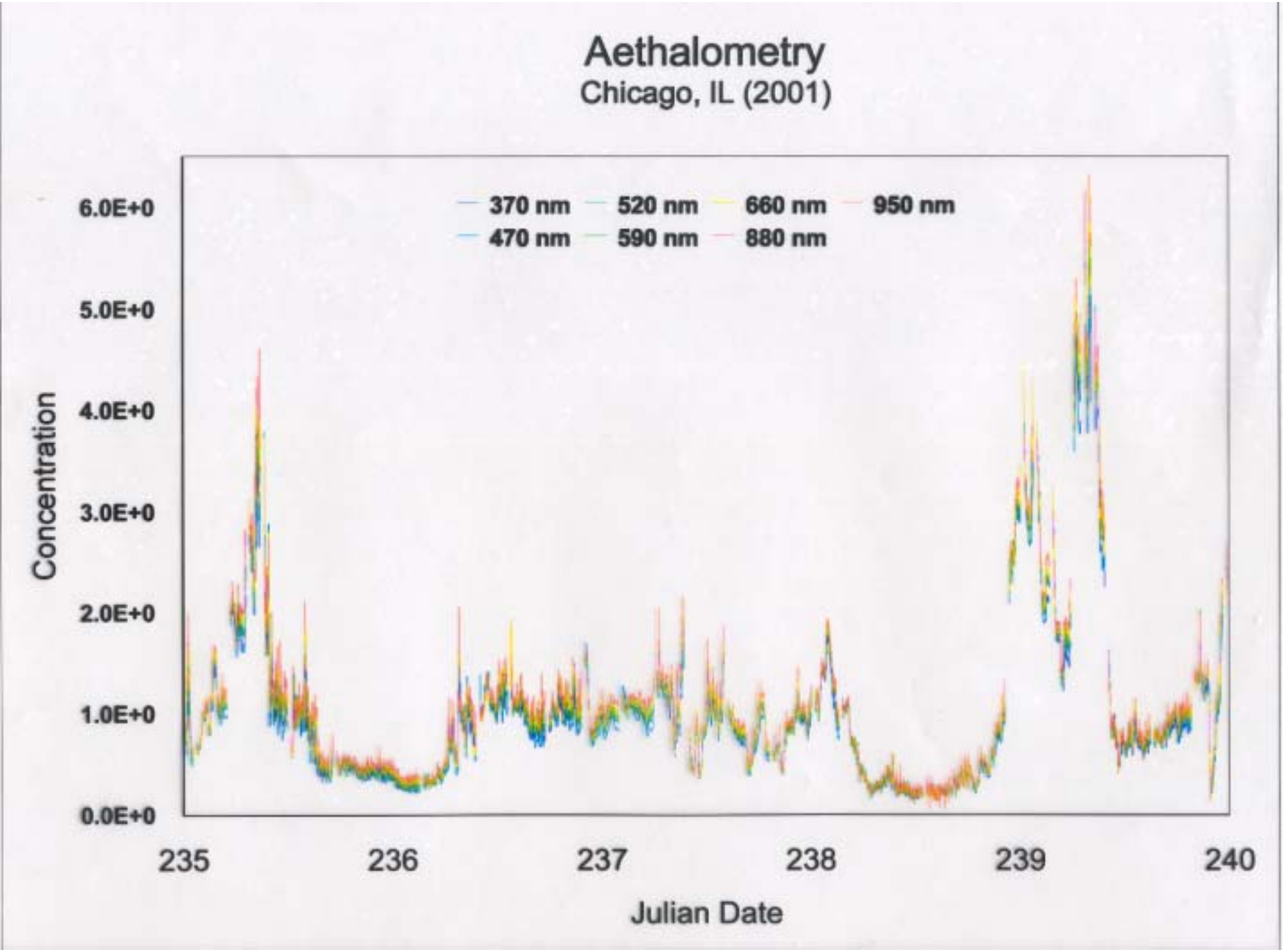
Apparent Ages for Aerosols – NETL

Sample	SIZE(μm)	CORR. AGE (days)
PA1	<1	17
PA2	>1	11
PA5	<1	19
PA6	>1	20
PA9	<1	21
PA10	>1	12
PA11	<1	18
PA12	>1	15
PA13	<1	30
PA14	>1	27
PA17	<1	10
PA18	>1	30
PA21	<1	12
PA22	>1	25
PA25	<1	24
PA26	>1	32
PA29	<1	31
PA30	>1	46

OK SO WHAT IS CAUSING THIS?

BLACK CARBON?


ANDERSEN
Aethalometer™


Aethalometry
Chicago, IL (2001)
370 nm
470 nm
520 nm
590 nm
660 nm
880 nm
950 nm
6.0E+0
5.0E+0
4.0E+0
3.0E+0
2.0E+0
1.0E+0
0.0E+0
Concentration
235
236
237
238
239
240
Julian Date

Daytime Attack!

O_3 OH NO NO_2 hν

Nighttime Attack! - NO_3

```
H H H  H H H H H H H H H H  H H H H H H H H  H
\ \ \  \ \ \ \ \ \ \ \ \ \  \ \ \ \ \ \ \ \ \  \
~C-C-C=C-C-C-C-C-C-C-C-C=C-C-C=C-C-C-C-C=C-
 / /    / / / / / / /      /    / / /
 H H    H H H H H H H      H    H H H
```

OILY CARBONACEOUS SOOT SURFACE

After Reaction – STILL PRETTY HYDROPHOBIC!

```
H H H  H  HO H H H H H  H H H H H HO H  H   H
\  \ \  \    \ \ \ \ \ \  \ \ \  \ \   \ \ \   \
~C-C-C =O  O=C-C-C-C-C-C-C-C-C=O  O=C-C-C=C-
 /  /            / / / /  / / /          /
 H  H           H H H H H H  H          H
```

OILY CARBONACEOUS SOOT SURFACE

AEROSOL INDIRECT

EFFECTS

CLOUD FORMATION

PARTICLES IN CLOUDS?